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EARTHWORK AND ITS COST

A HANDBOOK OF EARTH EXCAVATION

BY

HALBERT POWERS GILLETTE

Editor of Engineering and Contracting

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PREFACE AND INTRODUCTION

With respect to books on "methods and costs," three errors are commonly made by those who might profit from such books. First, that much of the text is out of date when it is ten or more years old. Second, that published unit costs are of little or no use, especially if wages and prices have changed since the publication. Third, that the study of methods and "tricks of the trade" is not a very good mental training.

Taking the last of these errors first, we find that many professors of civil engineering still have a somewhat exaggerated admiration for "general principles," coupled with an equally exaggerated contempt for "practical details" as mental food for their students. Professors of mining engineering have erred in this manner with much less frequency, probably because their primary aim has been to train men for managerial positions rather than as designers. It was my good fortune to take a course in mining engineering under Prof. Henry S. Munroe at Columbia University. Part of that course consisted of lectures on the methods and costs of excavation, followed by two summers spent in mining in Michigan and Pennsylvania. Thus I formed the habit of observing, analyzing and comparing excavation methods and costs under varying conditions. To the formation of that valuable habit, and an extension of it to other kinds of construction work, I owe in large measure my subsequent success in the field of civil engineering. I mention this to indicate the mental-training value of collecting and analyzing cost data.

If some professors of civil engineering are making a mistake in not training students as analysts of costs and observers of methods, an equally serious mistake is made by contractors and superintendents of construction. These men are justly proud of their "practical knowledge," by which they usually mean only the knowledge gained by their own experience. They usually fail to realize that the experiences of hundreds of other men, just as "practical" as they are, have been recorded in print, often in very great detail. Surely it can not be their contention that printed information as to money-saving methods and machines is useless to "practical men"; yet, were we to judge merely by their tendency not to read such matter, we should conclude that among

"practical men" there is scant respect for the printed page. I prefer to think that this seeming lack of respect is ascribable mainly to bad habits rather than to illogical thinking. "Practical men" usually have not formed the good habit of systematically reading practical books and articles. A few still labor under the delusion that there are no such books and articles, but most of them are habituated to field work, and not at all habituated to book work. The trouble lies there, and the cure of it — if cure there is to be — is in the medicine that such books as this contain.

As to the out-of-dateness of old text, and particularly of old cost data: Sixteen years ago the first edition of this book was published. I have retained three-fourths of that old book in this third edition, yet most of the matter in that first edition was fully ten years old when the first edition was printed. As one example, I have used cost data published by Elwood Morris in 1841, because neither the tools (drag scrapers) nor the methods described by him have changed materially. In another instance, and for a similar reason, I have referred to cost data published by George J. Specht in 1885; his data related to fresno scraper work, and are as useful today as they were 35 years ago.

In spite of the fact that new machines and improved methods are constantly being introduced, old devices and methods frequently continue to be economic under certain conditions. The Chinese are credited with the invention of the wheelbarrow countless centuries ago, yet it remains a useful tool to this day. I venture to say that if we were to find ancient but complete Chinese cost data on shoveling and wheeling earth, we could apply those data now. Yet common labor wage rates in China might have been only a twentieth or a thirtieth of what they are in America today. The point that I wish to make is this: Complete and well-analyzed cost data contain the number of hours or days work per unit (such as the cubic yard) of work done, together with a statement of conditions. Hence any change in wage rates does not destroy the value of such cost data, for it is a simple matter to substitute existing wage rates and calculate the present cost.

In the preface of the first edition I said:

"There are few engineering works of magnitude that do not involve the excavation of earth. Indeed, the cost of earthwork forms one of the greatest of cost items in canal, in reservoir and in railway construction, nor is it an inconsiderable item in the construction of roads, sewers or water works. What will this excavation cost? This is a question that the engineer first asks himself in making his preliminary estimates. Later the same

question confronts the contractor. To the engineer an erroneous answer may mean loss of reputation; to the contractor it assuredly means ruin where the work is extensive. A glance at the wide range in contract bids for most earthwork jobs will convince any one that few contractors do more than guess at costs. While the numberless engineering structures that have cost more than the preliminary estimates prove quite as conclusively that engineers too often guess also.

"In this the first published volume treating of earth economics in a comprehensive way, I have given all that my own notes could furnish and all that I have found in print in American technical literature. But I have not confined the exposition to a bare recital of facts and figures, since the principal aim has been to outline rational methods and rules to be used in cost calculation."

Shortly after the first edition was published, a non-technical friend remarked: "I am amazed at your being able to find enough matter to fill 200 pages on dirt." Whether his amazement would now be six-fold as great as then, one can but guess. His surprise, however, is typical of that of almost every non-technical man on first looking into the literature of a narrowly technical subject like earthwork. I could easily have doubled the size of this book, without going outside the best articles that have been published during the last thirteen and one-half years in Engineering and Contracting under my editorial direction. But the limited demand for expensive, large books of this character necessitates a restriction in size. However, quite a complete bibliography is given at the end of each chapter, by which readers may be guided to many excellent articles on earthwork not abstracted in this book.

For assistance in abstracting articles and compiling data for this book, I wish to acknowledge my indebtedness to Arthur P. Ackerman and H. C. Lyons.

HALBERT P. GILLETTE.

Chicago, Ill., Feb. 23, 1920.

TABLE OF CONTENTS

CHAPTER I

PROPERTIES OF EARTH

Composition of Earth. Earths or soils are the insoluble residues from the weathering of rocks. Soils from whatever source derived are mixtures of sands and clays, and they differ principally in the relative proportions of sand or siliceous material to the clay or argillaceous matter, and in the size of the grains. Residual soils are more varying in composition than soils that have been transported by water. The further and oftener a soil has been transported the more complete the separation of the clay from the sand.

Clay is generally the result of the decomposition and consequent hydration of feldspathic rocks, especially granite and gneiss. Clays from these sources usually contain more or less siliceous material; and, if this is separated, the residuum is found to consist of hydrated silicate of alumina with more or less lime, oxides of iron, magnesia, and alkalies. All soils found near the surface of the earth contain more or less organic matter. Clay is often the residuum of limestone, the calcite having been dissolved and leached out. Marly soils are the remains of old shell beds that have decomposed in this way.

Earths, therefore, are compositions mainly of silica and silicates of aluminum and other metals.

Kinds of Soils. Soils are sometimes named from the rock from which they have been derived; thus, a soil resulting from decomposition may be a *granite soil, limestone soil,* etc. More often, however, soils that have been transported are named after the agencies involved in their transportation; as *glacial soils;* or from their position, as *terrace soils;* or from their characteristics, as *sandy* or *clayey soils.*

The term *loam* is usually applied to mixtures of sand and clay containing organic matter. When the principal constituents of a loam is clay it is termed *clayey loam,* and when sand predominates, *sandy loam.*

Many local terms are applied to soils, and there is much variation in the use of earth and soil nomenclature, thus clay is called gumbo.

Some of the terms applied to earth and soils by writers on earthwork are as follows:

Adobe is the name given to a calcareous clay of a general gray brown or yellowish color, very fine grained and porous. This material forms the soil of a large portion of the rainless region of the United States in Colorado, Utah, Nevada, Southern California, Arizona, New Mexico, and Western Texas. It is derived from the waste of surrounding mountain slopes.

Alluvial Soil is river-borne material consisting of mixtures of sand and clay in varying degrees of fineness. It is usually loose in texture.

Black-waxy is a term applied to certain very fertile soils in Texas. They are a mixture of clay and organic matter, black in color and heavy to work.

Buck Shot Clay is a clay containing small concretions cemented with calcareous or ferrous material. These are about the size of buck-shot.

Bull-Liver is a term applied to a mixture of very fine sand, pulverized limestone and water, encountered in the excavations for the Chicago Drainage Canal. (E. R. Shanable, in *Trans. Asso. Eng. Soc.*, June, 1895.) This material when in place was very tough and difficult to excavate.

Catlinite, or Indian pipe stone, is an indurated clay found in the Dakotas.

Clay is a mixture of finely divided silicates of aluminum, iron, magnesium, calcium, and other metals. It seldom occurs without a small percentage of sand which has a greater effect on its characteristics than its chemical composition.

Glacial Soil, is an uneven mixture of clay, sand, gravel and boulders, carried and deposited by prehistoric glaciers. It is usually loose in texture but is sometimes very tough and even cemented.

Gravel is any soil which is composed chiefly of small stones. No definite line can be drawn between sand, gravel, and boulders; but, in general, material passing a ¼-in. screen would be counted sand, and stones too large to handle on a hand shovel would be called boulders. Pure gravel is loose in texture and easy to work. It often occurs with such a mixture of finer materials that each stone is tightly embedded. In this condition it will require picking.

Gumbo is a fine clay. It is extremely sticky and difficult to handle when wet.

Hardpan is the term applied to any extremely compact soil that is difficult of excavation. Geologically it is rock in the process of formation. It may be a clay that has become hardened by heat or pressure, or an incipient shale, or a sand or gravel that has been partially cemented by small amounts of iron oxide or carbonate of lime. Glacial deposits, consisting as they often do of nests of large size gravel and boulders in dense sandy clay beds, are often spoken of as hardpan. Most hardpans do not soften under the action of water when first taken out of the pit, but after being exposed to the air until dry they crumble rapidly into minute fragments when submerged.

Kaolin is pure aluminum silicate. Deposits of relative purity are worked for potters' clay.

Laterite is a red furruginous residual clay found in tropic and semi-tropic regions.

Loam is a mixture of sand and clay containing organic matter. It exists practically everywhere as the top soil which supports vegetation.

Loess is a clay, similar to adobe covering wide areas in the Mississippi Valley. It is in general wind-borne material.

Marl is a clay containing much calcium carbonate, the result of the decomposition of old shell beds.

Muck is a term applied to a variety of material. Thus in tunneling and many other forms of excavation the excavated material is called muck. The term is best applied to the slimy mud from pond bottoms and to similar material.

Muskeg is the mixture of mud, peat, and moss that occurs in wide areas in the swamps of Canada and northern United States.

Peat is decayed vegetable matter. Geologically it is coal in process of formation. It is light when dried, but always occurs in a water soaked condition.

Quicksand has been defined as a mixture of fine sand with such proportions of clay and loam as will enable the mass to retain water. The true quicksand, however, is an argillaceous material containing little or no silica or grit, and is usually leaden in color in its natural, water soaked state, and mainly white when thoroughly deprived of water. This material when wet and trampled upon begins to quake; it is therefore often called *quakesand*. If after having reached a condition where it quakes, it is left quiescent for a few hours, the particles settle down and expel the water, and it again becomes firm.

Three rules to be observed in excavating quicksand are as follows: (1) The water must be removed promptly and thoroughly; (2) the excavation must be made with the utmost dispatch; (3) the material must not be disturbed after it begins to quake.

When quicksand is encountered, ample dredging and pumping facilities should be provided. The pumps should be capable of lifting sand as well as water, and for this reason pumps of the steam siphon, steam vacuum, pulsometer, or centrifugal types are preferable. The ability of a pump to work without becoming clogged is of much greater consequence than a high efficiency in power consumption.

When thoroughly dry quicksand may be readily excavated, although at times it becomes so hard as to require picking. Lumps

of apparently dry quicksand may be made "quick" by the agitation caused through handling or hauling, and become difficult to remove from the wagons or cars in which they have been loaded.

Sand is any material more finely divided than gravel and not a fine as clay. In general it consists of silica or quartz in very small fragments. The size, shape, and gradations of fineness of the particles have an influence on the characteristics of the mass.

Shale is clay in process of changing to rock. It is usually soft and thinly stratified or laminated.

Sub-soil is the soil below the top soil; generally the material too deep to be disturbed by ordinary plowing. It is not so finely divided as the top soil and does not contain as much organic matter.

Top Soil is the upper layer of soil that is within reach of ordinary plowing. It is kept loose in texture by the growth and decay of plant roots.

Wacke is a compact, dark colored clayey soil resulting from the decomposition of basaltic rock.

Weight of Soils. Table I gives the weights of soils according to various authorities.

TABLE I — WEIGHT OF SOILS

Description	Per cu. ft.
Clays	
Potters' clay, dry and solid, T.	119
Potters' clay in lumps, T.	63
Heavy clay, S.	75
Half sand, half clay, S.	96
Clay, M.	63
Gravel	
Pit gravel, B.	122
Gravel mixed with clay, B.	155
Trautwine says gravel weighs about the same as sand.	
Loam	
Common arable soil, S.	80–90
Garden mould rich in vegetable matter, S.	70
Arable soil, M.	75.4
Old pasture soil, M.	65.6
Land 100 years in grass, M.	59.1
Common loam, perfectly dry, loose, T.	72–80
Common loam, perfectly dry, shaken, T.	82–92
Common loam, moderately rammed, T.	90–100
Mud	
Mud, dry, close, T.	80–110
Mud, wet, moderately pressed, T.	110–130
Peat	
Peat, dry, T.	20–30
Peat soil, S.	30–50
Humus (decayed vegetable matter, H.)	20.9

Sand

	Per cu. ft.
Dry siliceous or calcareous sands, S.	110
Quartz sand, M.	90.3
Sand, perfectly dry, loose, T.	90–106
Sand, perfectly dry, shaken, T.	92–110
Sand, perfectly dry, rammed, T.	100–120
Sand, sharp, very large and very small grains mixed, T.	117
Sand, voids full of water, T.	118–120
Sand, dry, B.	80–115

Shale

Shale in place, T.	162
Shale quarried, T.	92

Authorities. T. Trautwine, B. Byrne, "Inspector's Pocket Book." M, Murray, "Soils and Manures." S, Shubler, "Handbook of the U. S. Dept. of Agriculture," 1893.

Effect of Depth on Weight. In "Soils and Manures," J. A. Murray gives the following table of results obtained from trials made at Rothamsted in England:

	Wt. per cu. ft. Arable land	Wt. per cu. ft. Old pasture
Top layer, 9 in. deep	89.4	71.3
Second layer, 9 to 18 in. deep	93.2	94.8
Third layer, 18 to 27 in. deep	98.4	100.2
Fourth layer, 27 to 36 in. deep	101.4	102.3

This is of considerable interest from the standpoint of excavation. If we consider these results as applied to the excavation of a 36-in. trench they show that in the arable land the second half of the trench weighs 9.4% more than the first; in the old pasture the increase is 21.9%. The increase in density is of course less at greater depths but it is a factor worth remembering.

Specific Gravity. The specific gravity of the principal minerals of which soils are composed is:

Quartz	2.65
Feldspars	2.5–2.7
Calcareous minerals	2.7–3.0

Because of air spaces between the particles the apparent specific gravity of a cu. ft. of earth is less than that of the minerals of which it is composed. The range of apparent specific gravity for the soils in Table I is as follows:

Clays	1.01–1.91
Gravel	1.96
Loam	0.95–1.44
Peat	0.32–0.48
Sand	1.45–1.85
Shale	2.60

See the author's "Handbook of Rock Excavation" for numerous data on specific gravity, voids, etc.

Gravel		
Gravel, M.	40°	or 1¼-1
Shingle, Fl.	39°	or 1¼-1
Gravel exposed to waves, Fl.	11°	or 5 -1
Loam		
Compact earth, M.	50°	or ¾-1
Vegetable earth, M.	28°	or 2 -1
Sand		
Dry sand, M.	38°	or 1¼-1
Wet sand, M.	22°	or 2½-1
Dry sand, R.	28°-30°	or 1¾-1
Sand subjected to waves on shore of Lake Erie, G.	5°	or 10 -1
Stone		
Rubble, Fl.	45°	or 1 -1
Broken stone, E & C	38° 28′	or 1⅓-1

Authorities. M, Molesworth, Fa, Fanning, Fl, Flynn, ("Irrigation Canals"), R, Rankine, G, Observation by the Author, *E & C, Engineering and Contracting*, May 30, 1906.

Greatest Height of Vertical Bank. The following table is given by Austin T. Byrne ("Inspector's Pocket Book").

Earth	Greatest depth of temporary vertical face
Clean dry sand and gravel	0 to 1 ft.
Moist sand and ordinary surface mold	3 to 6 ft.
Clay, ordinary	10 to 16 ft.
Compact gravel	10 to 15 ft.

Dry clay in place frequently stands at much steeper slopes than the angle of repose would indicate. C. S. Phelps in *Eng. News*, July 1, 1896, says that in South Carolina clay cut at ½ to 1 stands better than at 1½ to 1, because the clay bakes in the sun and the steeper slopes shed water without saturating. In *Engineering News*, Sept. 13, 1900, H. C. Miller gives examples of 1 to 5 slopes in Brazil that have stood for years. Many railroads use a slope of ½ to 1 for the sides of cuts in clay.

Shrinkage. Earth always swells when excavated. On being deposited in a fill or embankment it shrinks. Obviously the amount of swell depends upon the compactness of the earth prior to excavation. The amount of shrinkage from the loose earth volume depends upon the means of compacting it, or upon the time a fill has stood, or both. Thus, if no means of compacting are employed, shrinkage may continue for years, whereas, after thorough compacting, there may be no subsequent shrinkage. The earth may or may not shrink to its original volume, or it may shrink to less than the original volume. As compared to original volume, ultimate shrinkage depends not only on the means of compacting and the time, but upon the compactness of

the earth before it was excavated. Any earth, no matter how compact in its original position, will shrink into smaller volume if sufficient means of compacting are employed. Ordinary tabulated percentages of shrinkage are useless. There is so much variation between earthwork jobs that the information that clay shrinks 10% is entirely inadequate, unless accompanied by statements of where it was excavated and where and how deposited.

The reader can best obtain data on shrinkage by having many examples set before him from which he can select those where conditions were nearest his own problem. Beginning with the results of observations by Elwood Morris, in 1841 (published in the *Proc. Franklyn Inst.*), data given in the first edition of this book and other data from more recent Engineering literature follow.

Railroad Embankment Built by Carts. Morris moved earth by means of carts and wooden drag scrapers, obtaining the following results:

Material	Excavation cu. yd.	Embankment cu. yd.	Shrinkage per cent.
Yellow clayey soil	6,970	6,262	10.15
Yellow clayey soil	25.975	23.571	9.25
Light sandy soil	10,701	9,317	12.93
Total	43,646	39.150	10.3
Gravelly earth (small scale experiment)			12.0

The railroad embankments built by Morris were deposited in layers; one-horse carts and wooden drag scrapers being the means employed in moving the earth. Work was begun one year and finished the next, so that fills went through one winter before final measurement. Note that the shrinkage had all occurred during the progress of the work.

Small Scale Experiments in India were made by Mr. J. H. E. Hart by digging trenches 2 ft. deep and 6 ft. wide, casting out the earth with shovels.

Trench No. 1 in "black cotton soil" measured 416 cu. ft., and the loose earth cast out measured 600 cu. ft., showing a swelling of 184 cu. ft. or 23%, which was checked by immediately shoveling the earth back into the trench, without ramming it, when 191 cu. ft. of loose earth were left over after filling the trench level full. During the long and very wet rainy season which followed, the earth in the trench settled; and as fast as it did so the loose earth was shoveled in, until at the end of the rainy season only 22½ cu. ft. of loose earth remained, showing an increase of 5.3% over the original measure.

Trench No. 2 in "gravelly soil" (2 ft. deep) showed a swelling of 25% when the earth was thrown out and measured loose in a

bank 1¾ ft. high; and, after settlement as before under heavy rains of one season, half the loose material remaining when the trench was first filled, was left, which was 12½% of the volume of the trench. In both these cases the earth had not been walked over or pounded when measured loose.

Swelling of Newly Excavated Material. A. Von Kaven, President of the Royal Polytechnic Institute in Aix-la-Chapelle, gives in his book on road building the following. According to a series of observations when material is first loosened it swells thus:

Material	Increase in volume
Sand	15 to 20%
Clay and sand	22%
Hard clay, lias	24%
Clay mixed with cobbles	26%
Solid gravel bank	28%
Soft rock which can be picked	30%
Hard rock	34 to 50%

While Von Kaven does not state how the material was loosened and measured, in common with other European authorities he doubtless refers to materials loosened with a shovel and not packed down afterward by traffic, rain or otherwise.

Swell of Material in Levees. Geo. J. Specht, in the *Trans. of the Technical Society of the Pacific Coast*, May 1, 1885, gives results of measurements made on levee work coming under his own observation. The levees were built in 1884 along the Feather and Sacramento Rivers in Sutter County, California. The levees were about 12 ft. high, 6 ft. wide on top and 90 ft. wide at the base with front slope of 1 to 3 and rear slope of 1 to 4. Material was borrowed from both sides for a distance of 100 ft. from the toe of the slope, and buck scrapers drawn by four horses were used to move the earth which was not rolled. A buck scraper drifted or pushed to place about 90 cu. yd. per day. The soil was well plowed before the fill was placed upon it to insure a good bond.

There are several noteworthy points of difference between this work and that of Morris already given. In the first place Sutter County, California, is a rainless district in the summer. Secondly the material was taken from the bed of a river and such material is always more dense than ordinary, due to the puddling action at times of high water. Thirdly no wheeled vehicles passed over the fill during construction, whereas a large quantity of loose earth was pushed into place with the long buck scrapers.

These factors, I believe, combined to make an unusually favorable condition for a swelling of earth when taken from cut to fill.

I would especially emphasize the fact that sandy earth in

the bottom of overflowed river valleys, and earth approaching hard pan in certain glacial deposits is very dense. Such earth is quite certain to occupy more space in fill than it did in cut, unless thoroughly rolled or rammed.

The results obtained by Specht were:

9,398 cu. yd. in cut (heavy adobe clay) made 9,470 cu. yd. fill, measured three weeks after finishing.

10,000 cu. yd. in cut (adobe in sandy loam) made 10,290 cu. yd. in fill.

29,000 cu. yd. in cut (adobe in sandy loam) made 30,330 cu. yd. in fill.

53,350 cu. yd. in cut (sandy loam, with small amount of adobe and hard pan) made 58,350 cu. yd. in fill, or about 9.4% increase.

202,634 cu. yd. in cut made 208,915 cu. yd. fill (3 months' work).

Shrinkage of Embankments. P. J. Flynn (*Engineering News*, May 1 and 8, 1886) collected a great array of data on earth swelling and shrinking; and reasoning erroneously by combining the shrinkage of the Morris embankments with the swelling of the Specht embankments, he reached the remarkable conclusion that a contractor should always be made to set his fill stakes 17% higher than the final fill was to be. His idea was that Specht had measured his fill immediately after completion, while Morris had waited until rains had settled it. This was erroneous reasoning.

The following data on bank shrinkage after the bank has been finished, are taken from the letters of contributors to a controversy on this matter in *Engineering News*, Nov. 15, 1900, and subsequent issues.

TABLE III — EARTH SHRINKAGE

Authority	Conditions of fill	Depth of fill, ft.	Vertical shrinkage
C. H. Tutton	Pit gravel for railway fill by wagons	14	8⅛% after 6 mo.
" "	Pit gravel for failway fill by wagons	14	9½% after 12 mo.
H. P. Gillette	Gravelly dike, made by wheelers	15	3% after 4 yr.
" "	Sandy loam Erie Canal bank	22	3% after 50 yr.
" "	Gravelly road embankment by dump cars	16	3½% after 1 yr.
Chas. R. Felton	Sand and gravel street fill by carts	5 and 6	1¼ to 1% after 4 yr.
" "	Same as above, by carts	7	2% after 4 yr.
" "	" " " " "	8	1% after 4 yr.
" "	" " " " "	10	2¼% after 4 yr.
" "	" " " " "	12	½% after 4 yr.
" "	" " " " "	16	2% after 4 yr.
" "	" " " " "	18–20	1½-2¼% after 4 yr.

Authority	Conditions of fill	Depth of fill, ft.	Vertical shrinkage
Woolsey Finnel	Railroad fills (actual levels). sand and gravel by wheelers		1% after 6 mo.
" "	Clay loam and earth, by wheelers		2 to 3% after 6 mo.
" "	Calico clay, and kaoline by wheelers		5% after 6 mo.
" "	Same as above, by carts		8% after 6 mo.
" "	Earth, carts, wagons, cars		4 to 10% after 6 mo.
" "	Same as above, by wheelbarrows		15 to 25% after 6 mo.
L. B. Merriam	Railway fills, by scrapers		3%
" "	" " by wheelers		5%
" "	" " by dump cars		7%
W. F. Shunk	Railway fills		2 to 4%

Shrinkage of Railway Embankment. *Engineering and Contracting*, March 19, 1919, gives the following: Specific instances of shrinkage of railway embankments were cited in a committee report submitted this week at the 20th annual convention of the American Railway Engineering Association. Information was given regarding 8 embankments between mileposts 540 and 553 on the Atchison, Topeka & Santa Fe Ry. The following tabulation compiled from the report shows the percentage of material required to restore the several embankments to their original width after a lapse of 4 years' time:

	Quantities in fill at completion, Nov., 1911 Cu. yd.	Quantities required to restore fill to original width of 18 ft., Nov., 1915 Cu. yd.	Amount of shrinkage Per cent.
Embankment No. 1	15,762	1,824	11.6
Embankment No. 2	147,582	6,995	4.7
Embankment No. 3	125,680	2,371	1.9
Embankment No. 4	19,067	99	.5
Embankment No. 5	150,852	664	.4
Embankment No. 6	57,709	1,642	2.8
Embankment No. 7	33,902	1,678	5.0
Embankment No. 8	62,207	3,090	5.0

The base of embankment No. 1 was constructed from side borrow with fresnos. It was topped with wheelers and carts. The material was brown pack sand, gyp and joint clay. The base of embankment No. 2 was also made from side borrow with fresnos and wheelers. It was topped with cars. The material was the same as for No. 1. For No. 3 the base was placed with fresnos; it was topped with wheelers. The material was brown pack sand, gyp and joint clay. Several rains occurred during the period this fill was being placed which accounts for the small amount of shrinkage. The base of No. 4 was placed with fresnos; it was topped with wheelers using gyp and pack sand. The base

of No. 5 was placed with fresnos from side borrow; it was topped with machine and wagons. The material was red sandy clay and gyp. Fresnos were used in placing the base of No. 6; it was topped with wheelers. The material was brown sandy clay and gyp. During the time this fill was being put in there were several very heavy rains, which accounts for small amount of shrinkage. The fill for embankment No. 7 was made from side borrow with fresnos; the material was black sandy loam and clay. The fill for No. 8 was made from side borrow, the base being placed with fresnos and the top with wheelers. The material was black sandy loam and brown sandy clay and gyp.

Effect of Water on Clay Shrinkage. In the ninth annual report of the Boston Transit Commission, 1903, data on clay shrinkage are given by Howard A. Carson.

Experiments were made on 12-in. cubes of clay taken from the East Boston Tunnel which were dried for three days beside a warm stove.

Experiment No. 1, clay containing no sand, from East Boston Tunnel:

	No. 1	No. 2	No. 3
Shrinkage in volume	19.5%	19.3%	16.3%
Shrinkage in weight	21.4%	22.2%	21.4%
1 cu. ft. shrank to	0.8 cu. ft.		
1 lin. ft. shrank to	0.93 lin. ft.		

Experiment No. 2, clay containing 30% fine sand:

Shrinkage in volume	11.5%
Shrinkage in weight	18.6%
1 cu. ft. shrank to	0.9 cu. ft.
1 lin. ft. shrank to	0.96 ft.

Carson states in a letter to the author that the first tests were made upon 12-in. cubes of clay spaded from the tunnel but that later tests were made on clay cylinders 2 in. in diameter by 4 in. long placed in gasoline. Measurements were made by the displacement of mercury and the results were as follows.

Effect of water on volume of clay:

Water, per cent. of dry weight	Volume of clay per cent.
28	100
25	95
23	92
22	91½
21	90
19	88
18	87
16	83
15	82
14½	80
13	80

Plotted to scale these tests show that the volume varies almost exactly as the percentage of water.

European Experience with the Shrinkage of Clay. An article by Thanneur, Ing. Ponts et Chausses, is translated in *Engineering News*, April 2, 1887, by H. N. Ogden.

In the embankments built in 1874–1882 from the quarry-clay and green loam of the Coulomnieer district an allowance of 10 to 15% was made as compared with the excavation. But in spite of this precaution these embankments settled. Capt. Martin, of the English engineers, showed in a paper, read Mar. 23, 1882, that for certain miry loams the shrinkage attained 23.5%. Preliminary tests can alone determine the coefficient for any particular case; but prudence will indicate 25% as a minimum allowance.

This is borne out by experience in building the "new wall" at Calais. Here on the south front the ditch was dug in miry loam, and the difference in volume, between the excavation and material extracted, was so great as to be at first charged to error in calculation.

Experiments have been made as follows: An excavation was made specially of 5,174 cu. yd., the earth removed was levelled and tamped on a heavy timber platform, and when measured was found to contain 4,912 cu. yd. This dirt, however, was artificially moistened to compensate for drying; and, as the water already in the soil could not be measured, it was impossible to arrive at relative quantities of moisture. As a certain portion of this water drained off from the "filling," it is reasonable to conclude that the first settling, to the extent of about 5%, is explained by this loss of moisture. In the experiment above noted a cube (0.45 cu. ft.) weighing 50 lb., was taken from the levelled and pounded and still fresh earth. This cube kept for some days at the normal temperature dried quite rapidly, and after one year was reduced to a volume of 0.39 cu. ft. and weight of 45.5 lb.

Shrinkage of Rolled Earth Dam. The most valuable careful tests made in recent years are those described by Burr Bassell in his book on "Earth Dams" (also in *Engineering News*, July 10, 1902). Tests were made on the material used in the construction of the Tabeau Dam which was a mixture of 62% earth and 38% gravel.

Material in its natural bank weighed 116.5 lb. per cu. ft.

Material sprinkled and rolled in 6-in. layers in embankment weighed 133 lb. per cu. ft.

Material delivered by wagons moist and dumped loosely weighed 76.6 lb. per cu. ft.

Material dug out of dam embankment loose and shaken weighed 80 lb. per cu. ft.

The natural soil contained 19% of moisture, and 33% of water had to be added to fill all its voids, making a total of 52% of voids in the natural soil when loosened.

From the foregoing it is evident that the natural bank when loosened and placed in a wagon swelled 46%, which is a high percentage and indicates an unusually dense bank. Upon rolling the earth in the embankment there was a shrinkage of about 12% from the original place measure. Let it be noted that the rolled fill weighed 1¾ times as much as the loose moist earth and that its weight of 133 lb. per cu. ft. is almost as great as solid masonry! In fact, concrete often weighs no more than this earth dam embankment. For a description of the construction of the Tabeau Dam see the chapter on Earth Dams.

Shrinkage of Embankment of Hardpan and Boulders. The Forbes Hill Reservoir (Mass.) is described in *Engineering News*, Mar. 13, 1902. The embankments were made of clay hardpan containing boulders; a four-horse plow was required to loosen the hardpan. The following are the volumes of cut and fill:

Hardpan, measured before loosening	17,466 cu. yd.
Rolled hardpan embankment	15,474 " "
Shrinkage, 11.4% or	1,992 " "
Material excavated as above	17,466 cu. yd.
Estimated equivalent amount of stone (boulders, etc.), removed, 5.9% or	1,043 cu. yd.

While the item of stone removed is rather obscurely recorded it would seem that the natural bank really shrank 1,992 — 1,043 = 849 cu. yd. or less than 5% during the rolling. After the fill was finished it did not shrink at all during the winter following.

Shrinkage of Top Soil Under Rolling. The shrinkage of top soil rolled in 6-in. layers has been investigated in the construction of the North Dike of the Wachusett Reservoir, near Clinton, Mass., and is reported upon by Alex. E. Kastl, "The Technic" for 1902, *Eng. News*, Aug. 7, 1902. The length of the trench which was filled was 1,375 ft. About 500 ft. of this length was about 30 ft. deep, 30 ft. wide at the bottom, with side slope of 1 on 1. The remainder varied in depth from 0 to 25 ft., and in width from 50 to 80 ft. between slope stakes, with side slopes of approximately 1 to 1, having been partially filled under a previous contract. The soil was excavated from an area of 64 acres to an average depth of 0.78 ft. About 59 acres of this area contained stumps. The land from which the soil was excavated was called sprout land — land which has been cleared of forest growth and again allowed to grow over with trees and brush. The volume

of the soil measured in excavation was 80,355 cu. yd. The volume of the soil after it was deposited and compacted in the cut-off trench was 50,735 cu. yd. or 29,620 cu. yd. less than the volume measured in excavation. The final levels were taken a few days after the completion of the work. From the above it follows that the shrinkage of the soil was 37%, calling the volume of 80,355 cu. yd. 100%. This shrinkage includes roots ½ in. or more in diameter and stumps so far as they were originally embedded in the soil, but which were removed and burnt. Roots ½ in. or more in diameter, stumps or other wood were not allowed to be deposited with the soil in the cut-off trench. The soil was free from stones. The volume of the soil excavated was determined from levels taken when there was no frost in the ground. The first levels were taken after the ground was cleared of trees and brush, which were removed and burnt or otherwise disposed of, and before the contractor had commenced grubbing; and the final levels after the final excavation was finished. The volume of the soil excavation includes the roots and stumps so far as the same were embedded in the layer of soil excavated. The levels extended over the entire area stripped and were taken not more than 25 ft. apart, that is, not less than 70 cuts or depths of soil were determined for each acre. The ground was divided into squares 500 ft. on a side, the corners of which were permanently marked and the sides were used as base lines for the cross section work. The average depth given, 0.78 ft., is the total volume of the soil excavated divided by the area, and is only intended to give some idea of the depth of the soil stripping. All the soil containing 4% or more of organic matter is removed from the reservoir site. The volume of the soil when in the trench was calculated from accurate cross-sections, taken not more than 25 ft. apart before and after the filling of the trench. Before rolling the soil it was watered as much as it would bear without sticking to the roller. The type of roller which was used weighs about 6,000 lb., and is drawn by two horses. The cylinder of the roller is 5 ft. long and is composed of 19 cast-iron wheels, 3 in. thick at rim, 10 being 2 ft. 11 in. and 9 2 ft. 8 in. in diameter, respectively, arranged alternately.

The amount of shrinkage encountered on this work, 37%, is extreme, but was to be expected as forest top soil is the loosest of all soils; and rolling in thin wetted layers is a very efficient way of compacting.

Shrinkage of Embankment of Wachusett Reservoir. According to *Engineering News*, June 11, 1903, the North Dike of the Wachusett Reservoir was flooded after rolling, from May 19 to June 30. Small dikes were used to hold the water on an area of

4½ acres on the main dike which had been built up of 6-in. rolled layers to a height of 51 ft. Settlement after flooding ranged from 0.06 ft. to 0.26 ft., the average being 0.15 ft.

On a dike 40 ft. high built in 7.5-ft. layers without rolling the maximum settlement was 1 ft. and the average 0.47 ft.

Shrinkage of Rolled Embankment. In the construction of the Peterborough, Ont., lock on the Trent Canal the earth embankment, upon which the canal is carried up to the back of the breast wall, was built in layers about 8 in. in thickness, thoroughly compacted and rolled. During the hot and dry season the earth filling was liberally watered. The material was clay containing small stones. This method produced an embankment having the remarkable record for settlement of only about 0.1 ft. in a period of nearly a year where the depth of fill was upwards of 40 ft.

Increase in Volume of Dredged Material. In the construction of the Buffalo Breakwater, which is described by Emile Low in "Trans. Am. Soc. C. E.," Vol. 52, the total quantity of material dredged was as follows:

	Cu. yd.
Season of 1897 by dipper dredge	8,117
" " 1898 " " "	4,934
" " 1898 by clam-shell dredge	193,810
Total scow measurement	206,861
Total place measurement	192,258
Swelling 17.6%, or	14,603

The following results have been found on the United States Public Works:

Material	Increase of scow measurement over place measurement
Rock (large fragments make greater increase)..	75 to 100%
Sandstone and limestone	30%
Very soft mud	13%
Soft blue mud	15%
Hard sand with small admixture of silt	20–30%
Loose muck dredged from reservoir	15–17%

With the hydraulic suction dredge where much fine light material is encountered the scow measure will be equal to or less than the place measure.

Summary. From this varied mass of data we may deduce the following general rules:

1. Taking extreme cases, earth swells when first loosened with a shovel, so that after loosening it occupies 1⅐ to 1½ times as

much space as it did before loosening; in other words loose earth is 14 to 50% more bulky than natural bank earth.

2. As an average we may say that clean sand and gravel swell 14%; loam, and loamy sand and gravel, 20%; dense clay and dense mixtures of gravel and clay, 33 to 50%.

3. That this loose earth is compacted by several means: (a) the puddling action of water, (b) the pounding of hoofs and wheels, (c) the jarring and compressive action of rolling artificially.

4. If the puddling action of rains is the only factor, a loose mass of earth will shrink slowly back to about its original volume; but an embankment of loose earth will at the end of a year be still about 8% greater than the cut from which it came.

5. If the embankment is made with small one-horse carts, or wheel scrapers, at the end of the work it will occupy 5 to 10% less space than the cut from which the earth was taken; and in subsequent years will shrink about 2% more, often less than 2%.

6. If the embankment is made with wagons or dump cars, and made rapidly in dry weather without water, it will settle vertically, 3 to 10% in the year following the completion of the work and very little in subsequent years.

7. The height of the embankment appears to have little effect on the percentage of its subsequent shrinkage.

8. By proper mixing of clay or loam and gravel, followed by sprinkling or rolling in thin layers, a bank can be made weighing 1¾ times as much as loose earth, or 133 lb. per cu. ft.

9. The bottom lands of certain river valleys and banks of cemented gravel or hardpan are more than ordinarily dense and will occupy more space in fill than in cut, unless rolled. Dry clay taken from deep cuts will absorb and hold additional moisture in embankment and will be accordingly increased in volume.

10. Dry, tough clay often breaks into chunks resembling shale, and then swells when first loosened almost as much as rock.

Bibliography. "A Treatise on Rocks, Rock Weathering and Soils," George P. Merrill. "Soils and Manures," J. Allen Murray. "Practical Designing of Retaining Walls," Wm. Cain (cohesion and friction).

"Bulletin No. 64," Bureau of Soils, U. S. Dept. of Agriculture, 1900.

CHAPTER II

MEASUREMENT, CLASSIFICATION AND COST ESTIMATING

Earthwork Definitions. The American Railway Engineering and Maintenance of Way Association have standardized definitions which are given in their "Manual" for 1915 as follows:

Group A — General.

CLASSIFICATION.— Arranging the material in groups according to its character.

CONTRACT.— A written agreement between two or more parties specifying terms, conditions, etc., under which certain obligations must be performed. (Specifications are a part of the contract.)

ESTIMATE (noun).—(a) A statement of work performed or material furnished, according to which payment is to be rendered.

ESTIMATE (noun).—(b) A statement showing the probable cost of a proposed piece of work.

ESTIMATE (verb).— The act of making an estimate.

QUANTITIES.— The amount of material to be handled, expressed in the usual units.

SLIDE.— The movement of a part of the earth under the force of gravity.

SPECIFICATION.— That part of the contract describing the materials for or the details of construction.

STOCK-PASS.— A culvert or bridge opening under the track, primarily for the passage of stock.

UNIT PRICE.— The price per unit of the various quantities specified in a contract for which a certain work is to be performed.

WASHOUT.— The carrying off of the permanent way by the impact and erosion of waters.

Group B — Right-of-Way.

RIGHT-OF-WAY.— The land or water rights necessary for the roadbed and its accessories.

ROADBED.— The finished surface of the roadway upon which the track and ballast rest.

ROADWAY.— That part of the right-of-way of a railway prepared to receive the track. (During construction the roadway is often referred to as the "grade.")

STATION GROUNDS.— Property to be used for station purposes.

Group C — Technical.

ALINEMENT.— The horizontal location of a railway with reference to curves and tangents.

CENTER-LINE.— A line indicating the center of an excavation, embankment or track.

CONSTRUCTION STATION.— The center line stake set at the end of each full 100-ft. tape or chain length (commonly called a "station").

CONTOUR.— The line of intersection between a horizontal plane and a given surface.

CROSS-SECTION.— A section through a body perpendicular to its axis.

CENTER STAKES.— Stakes indicating the center line.

ELEVATION OR HEIGHT.— The distance of any given point above or below an established plane or datum.

FINISHING STAKES.— Final stakes set for the completion of the work.

GRADE (verb).— To prepare the ground for the reception of the ballast and track.

GRADE-LINE.— The line on the profile representing the tops of embankments and bottoms of cuttings ready to receive the ballast.

GRADIENT.— The rate of inclination of the grade-line from the horizontal.

LOCATION.— The center line and grade line of a railway established, preparatory to its future construction.

PLAN.— A drawing furnished for guidance of work.

PROFILE.— The intersection of a longitudinal vertical plane with the ground and established gradients; or a drawing representing the same.

SLOPE.— The inclined face of a cutting or embankment.

SLOPE STAKES.— Stakes set to indicate the top or bottom of a slope.

SUBGRADE.— The tops of embankments and bottoms of cuttings ready to receive the ballast.

TOP OF SLOPE.— The intersection of a slope with the ground surface in cuts, and the plane of roadbed on embankment.

TOE OF SLOPE.— The intersection of a slope with the ground surface in embankments, and the plane of roadbed in cuts.

Group D — Clearing.

BRUSH.— Trees less than 4-in. stump-top diameter, shrubs or branches of trees that have been cut off.

CLEARING.— Removing natural and artificial perishable obstructions to grading.

GRUBBING.— Removing the stumps and roots.

Group D — Drainage.

BOG.— Soft, spongy ground, usually wet and composed of more or less vegetable matter.

CHANNEL.— The depression or cut in which a stream is confined.

CULVERT.— An arched, circular or flat covered opening of timber, iron, brick or masonry, carried under the roadbed for the passage of water, or for other purposes.

DRAIN.— An artificial waterway for conducting water from the roadway.

DRAINAGE.— The interception and removal of water from, upon or under the roadway.

DITCH.— An open artificial waterway for providing drainage.

INTERCEPTING DITCH.— An open artificial waterway for preventing surface water from flowing over the slopes of a cut or against the foot of an embankment.

SUBDRAIN.— A covered drain, below the roadbed or ground surface, receiving the water along its length by absorption or through the joints.

TRENCH.— A narrow, shallow excavation to receive a structure.

WATERWAY.— A channel, either natural or artificial, for conducting the flow of water.

Group F — Grading.

AVERAGE HAUL.— The mean distance material is to be hauled.

AVERAGE TOTAL HAUL.— The average total distance material is to be hauled.

BENCHED.— Formed into a series of benches.

BERME.—(a) The space left between the top or toe of slope and excavation made for intercepting ditches or borrow pits. (b) An approximately horizontal space introduced in a slope.

BORROW (verb).— To take material from a borrow pit.

BORROW (noun).— Material removed from a borrow pit.

BORROW PIT.— An excavation made for the purpose of obtaining material.

EMBANKMENT (or Fill).— A bank of earth, rock or other material constructed above the natural ground surface.

EXCAVATION (or Cutting).—(a) The cutting down of the natural ground surface; (b) The material taken from cuttings, borrow pits or foundation pits; (c) The space formed by removing material.

FOUNDATION PIT.— An excavation made for laying the foundation of a structure.

HAUL.— The distance material is moved in the construction of the roadway.

FREE HAUL.— The distance within which material is moved without extra compensation.

OVERHAUL.— The number of cu. yd. moved through the overhaul distance multiplied by the overhaul distance in units of 100 ft.

OVERHAUL DISTANCE.— The distance beyond the free-haul limit that material is hauled in constructing the roadway, for which extra compensation is allowed.

RAMP.— An inclined approach.

SHRINKAGE.— The contraction of material.

STEPPED.— Formed into a series of steps.

TAMPED (or Packed).— Packed down by light blows.

TOTAL HAUL.— The total distance that material is to be hauled.

WASTE.— Material from excavation not used in the formation of the roadway.

WASTE OR SPOIL BANKS.— Banks outside the roadway formed by waste.

Group G — Tunnels.

CURB.— A broad, flat ring of wood, iron or masonry, placed under the bottom of a shaft to prevent unequal settlement, or built into the walls at intervals for the same purpose.

ROCK.— A solid mass of mineral substance.

SHAFT.— A pit or well sunk from the ground surface above into a tunnel for the purpose of furnishing ventilation or for facilitating the work by increasing the number of points from which it may be carried on.

TUNNEL.— An excavated passageway under ground or water.

WELL (or Sump).— A cistern or well into which water may be conducted by ditches to drain other portions of a piece of work.

Measurement. Earthwork is measured and paid for by the cubic yard or cubic meter. Usually the measurement is of earth "in place," that is in the natural bank, cut or pit, before loosening. This is called "place measurement." Where small embankments are built from side borrow or from other irregular pits, it is more convenient to measure the material in the embankment, and there is no reason why this should not be done. Levees and dikes are usually paid for by the cubic yard of compact embankment, the allowance required for shrinkage being given in the specifications and stated to apply to the slopes as well as the top of the dike. Structures built by hydraulic fill are measured in embankment. Dredging is often paid for by measurement in scows.

Measurement "in place" is most satisfactory and should ordinarily be adhered to for all "useful excavation," that is, where material is cleared away from required space to make room for a building, railway, canal or other structure. Excavation done to procure material for building embankments is called "borrow." This, too, should be measured in place if the borrow pits can be

readily cross-sectioned and if the means of transportation are such that none of the material is lost; otherwise it is best measured in embankment. But in any case the specifications should say how measurement is to be made; and if in embankment, they should say how soon after completion the embankment is to be measured and what, if any, allowance is to be made for shrinkage.

On railway and other similar work "useful excavation" from cuts is used to build nearby embankments. This material is not paid for twice, but it is specified that it shall be hauled a certain minimum distance, called "free haul," without extra compensation. Transportation beyond this distance, called "overhaul," is paid for in cents per cu. yd. per 100 ft. of overhaul. When the distance from cut to fill becomes so great that the cost of overhaul is greater than the cost of excavation, material from the cut is wasted, and a borrow pit is opened to obtain material for the embankment. In this case double payment is made, one for the yardage borrowed, and one for the yardage wasted.

Legality of Methods of Calculating Earthwork. It is not the author's intention to discuss methods of staking out, measuring and calculating volumes in this book. These operations are classed as surveying, and information concerning them is readily available in books on that subject. One point however in which some of the text books are misleading is that they lay undue emphasis on the value of the prismoidal formula. The method of computing by average end areas is equally accurate if intelligently used, is much simpler, and has the sanction of the courts. The laws of some states provide that "in the absence of any specified agreement as to measurement," the "average end-area" formula must be used.

Search No. 774 in the library of the American Society of Civil Engineers gives references on the law of New York State in regard to the calculation of earthwork.

In a law suit over a contract for railroad building in South Dakota the court favored the prismoidal formula over the average end-area method of computation. That this decision was brought about by the misuse of the average end-area method is shown by the following, which is taken from a history of the case by Francis C. Tucker in *Jour. Asso. Eng. Soc.*, Vol. 15, 1895.

Another reason for large differences in quantities was that the engineers of the Railroad Company substantially gave the true prismoidal quantities, while the quantities given by the sub-contractor's engineer were obtained by averaging end areas without correcting in any way for the most extreme differences in consecutive cross-sections, although he took his cross-sections much

further apart, usually, than the Company's engineers did, thereby much increasing the need of correction. He carried the method of averaging end areas to the extreme of using it at both ends of every cut on side-hill; that is, he invariably treated material which was actually pyramidal in form as being wedge-shape, thereby increasing the quantity by 50%. An attempt was made in the evidence to show that custom had established the method of averaging end areas without correction; in effect, legalizing it. To disprove this the defendants introduced in evidence the following portions of standard works:

Computation from Diagrams of Railway Earthwork, Wellington. Preface, page 4.

"Economic Theory of Location of Railways, Wellington." Page 896, articles 1257 and 1258.

"Field Engineering," Searles. Page 203, article 235; page 225, article 254; page 229, article 256; page 236, article 263; page 200, article 231; page 201, article 232.

"Excavations and Embankments," Trautwine.

"Engineer's Pocket-Book," twenty-fifth thousand; page 161, Trautwine.

"Mensuration of Volumes." Page 129, Davies' Legendre.

They also claimed a strict interpretation of the contract, which says: "Payment being made only for number of yards actually removed by contractor, within the specified slope, grade and surface planes," and "Earthwork will be computed from cross-section notes of excavation prisms; that is, the quantities between the slope, grade and surface planes shall be taken, and shall be paid for by the cubic yard of twenty-seven (27) cubic feet."

To show the importance of this question of methods, and the extortion that an unscrupulous engineer might perpetrate by a judicious misuse of the averaging end-area method without correction, several test cases were selected from the cross-sections as measured and used by the sub-contractor's engineer, models were made and put in evidence, and the differences between the two methods of computation amply testified to. In one instance that engineer added, according to his own measurements, in a prismoid only 32 ft. long, 439 cu. yd. of excess, and this in solid rock.

The following from "Wellington's Economic Theory of Railway Location," correctly and concisely states the proper use of the two methods of calculating volumes:

"The nature of the error in the method of computing by average end areas is this: The error increases as the square of the difference in center height, and is not in the least affected by the absolute volume of the solid. The heavier the work, therefore, or the less the sudden changes of profile, the less the proportionate error. That cut is an unusual one in which the error is more

than 5 per cent, and that section of road would be very unusual on which the error was more than 1 per cent, and this error is always in excess. There are indeed certain possible solids in which the error will be in deficiency and certain others (those whose width on top is the same while the center heights differ, or vice versa) in which the end-area method is precisely correct, while certain methods by the prismoidal formula which appear much more exact will give a deficiency; but except on perhaps one solid in a thousand averaging end areas always gives an excess of volume.

"All methods of computing volume by first transforming the end sections into equivalent level-sections introduces a constant tendency to deficiency, and for that and other reasons are worse than useless labor, far simpler methods giving a more accurate result. The proper method of computing earthwork in construction is to compute by end areas only, and then at any later time when convenience serves to determine prismoidal corrections for those solids which need it only, which are those differing by more than two or three ft. in center height."

In *Engineering News*, Dec. 13, 1902, I deduced a simple correction formula for calculating earthwork by which the "mean end-areas formula" results can be corrected with ease and rapidity. I also derived the following rule for accurate use of the mean end-areas formula:

Take cross-sections so close together that no cut or fill shall exceed by more than 50% the corresponding cut or fill in the previous cross-section; except that where the previous fill is 0 the next cut or fill must be 2 ft. or less.

Classification of Excavation. There is no scientific distinction between earth and rock, the line of demarcation being entirely arbitrary. Various classifications have been used on different works, but none yet devised is entirely satisfactory, and no phase of earthwork is so fruitful of disputes with contractors as this.

The old test for earthwork, now generally discredited, was that material which could be plowed by a four-horse or a six-horse team should be classed as earth, and all other material as rock. This test had many limitations and disadvantages. Much material exists that cannot be plowed, yet is not called rock. Plows cannot be used at all on the rough surfaces of steam shovel cuts, and the test is utterly useless on frozen ground.

It has been suggested that a better test would be to classify as rock all material in which holes for blasting must be drilled; material in which holes for blasting can be made by *driving a bar*

at a specified rate per minute, would then be classed hardpan; and material in which a bar can be driven at faster than the specified rate, as average earth.

A better way out of the difficulty is to avoid verbal classification entirely, marking on the profile what the materials are in each cut, and specifying that payment will be made for materials, as classified on the profile, and not otherwise. This, of course, involves thorough exploration of the ground during the survey; but such an exploration should usually be made in any case.

Specifications for the Classification of Excavation were suggested by James H. Bacon in a paper before the American Society of Engineering Contractors, Jan., 1910. The following is taken from an abstract of his paper appearing in *Engineering and Contracting*, Feb. 23, 1910:

There should be only three classes of excavated material, not including excavation under water, or excavation or removal of any artificial work such as old masonry, etc. These three classes should be: (1) Solid rock. (2) Loose rock. (3) Common excavation.

Common Excavation. In many specifications the dividing line between common excavation and loose rock is determined by the "plow test"; this test should be discarded entirely as unsatisfactory. There are thousands of acres, which may in the future be crossed by railways, where the material to be moved has not the faintest resemblance to rock and where no sane man would attempt to break ground with a plow. The plow test is impossible, and the logical result, if the specifications provide this test, is that such material must be classed as loose rock.

Many of the western roads have discarded this test and specify that "all material not classed as loose or solid rock shall be common excavation." The companies using this specification specify that loose rock shall be any rock that can be removed without blasting, although blasting may occasionally be resorted to, or any rock in detached masses varying in size between given limits, and that solid rock shall be rock in masses that cannot be removed without blasting. It will be noticed that these specifications require a definition of the word "rock."

Mr. Bacon submits the following specifications for excavated material:

In these specifications the word "rock" shall be interpreted to mean any portion of the consolidated material forming the crust of the earth which has a greater volume than 1 cu. ft. Unconsolidated materials, such as sand, gravel, clay, hardpan, are not rock under these specifications.

Solid Rock. All rock in masses that cannot be removed without

drilling and blasting. All boulders or detached pieces of rock that measure 1 cu. yd. or more in volume.

Loose Rock. All rock which is loose or soft enough to be removed without blasting, although blasting may, at the option of the contractor, be occasionally resorted to. Detached pieces of rock measuring in volume from 1 cu. ft. to 1 cu. yd.

Common Excavation. All material not solid or loose rock.

The sizes specified for boulders and detached pieces are of course subject to be changed according to varying circumstances. No tests are recommended, as the writer believes that they would serve no useful purpose and tend to cause complications.

Excavation Under Water. This classification should be applied to all channels and pits under water which cannot be drained by ditching. The price or prices paid should be per cubic yard and should cover all material and labor, including coffer dams, necessary to do the excavation required. There should be at least two classes — i. e., with and without coffer dams. In many cases special specifications would be necessary.

Overhaul. Overhaul should be paid for, a price fixed by the company, per cu. yd. per hundred feet beyond the free haul, and the method by which overhaul is to be calculated should be described. The price should equal the cost of the work and is therefore a variable quantity. The limit of free haul is also variable. Both price and free haul limit should be accurately fixed for each section.

A Cassification According to Difficulty of Picking. Wm. O. Lichtner, in *Engineering and Contracting*, Sept. 17, 1913, outlines a system of classification that has been used with success in taking time studies on sewer work.

Many varying materials were encountered on this work ranging from fine dry quicksand, through stiff clay to solid rock. Attempts to classify and study these materials according to ordinary methods were unsuccessful although made with very great care. It was found that considerable difference existed from day to day in the cost of excavating what appeared to be the same material.

A new set of time studies were made, adopting a new classification based on two variables, first, on the time it takes to pick the material, and secondly on the time it takes to shovel the material after it is picked. The material to be excavated then would be designated by two capital letters like BA. The first letter always designated the picking element and the second letter the shoveling element. By time studies the amount of time it would take a man to pick one cu. ft. of material was determined and classified as B picking; also a time per cu. ft. was

determined for C picking, etc. In a similar manner, time per cu. ft. was determined for all kinds of shoveling. The picking classification, which was always the first letter and always made with a capital, was as follows:

A — No picking required.

B — Loosens uniformly into fine material, with no appreciable lumps, and picks easily.

C — Loosens easily into its component parts like a non-homogeneous material, as gravel mixed with sand, clay, or loam. Gravel less than 50% and not large.

D — Same as B except pick does not enter readily.

E — Loosens into lumps like a homogeneous material, not as hard as J.

F — Loosens hard into component parts like a non-homogeneous material as a cemented gravel.

G — Loosens into lumps and picks hard like a homogeneous material which is brittle.

H — Loosens into lumps. Material very tenacious.

I — Loosens into large lumps with very little fine.

J — Loosens hard on account of pick striking stones.

K — Loosening small boulders in trench (1 man size).

L — Loosening large boulders in trench.

M — Sledging rock.

The shoveling classification, which was always the second letter and always made with a capital, was as follows:

A — Finely divided material which heaps up on shovel.

B — Finely divided material which does not heap up on shovel.

C — Lumpy and fine material mixed.

D — Loose material like sand, clay, or loam, mixed with small gravel.

E — Same as D except large gravel.

F — Finely divided material. Can be spaded easily and requires no picking.

G — Supersaturated clay which can be shoveled.

H — Supersaturated clay which must be baled out in buckets.

I — Supersaturated material with small boulders which is baled out in buckets.

J — Sticky material which adheres to shovel.

K — Large lumpy material which averages 1 to 2 lumps per shovel.

L — Lifting small boulders from trench (1 man size).

M — Lifting large boulders from trench.

This classification has been used with great success for some time now and is a most satisfactory classification for practical

purposes. The determination of the time for each one of these items is a matter of time study which can be readily accomplished. Studies will have to be made, of course, to take care of the great number of variables, and tables compiled accordingly.

Railway Specifications of Classification. W. F. Dennis presented a paper in *Trans. Am. Soc. C. E.*, June, 1907. An abstract of this paper appears in *Engineering and Contracting*, Jan. 30, Feb. 6, and April 10, 1907. Mr. Dennis says in part:

Nearly all railroads find it useful to retain classification in their forms of agreement. Such classification gives a solid rock material at one end and an earthy material at the other, with generally an intermediate material called loose rock, and frequently an additional hardpan classification, formerly more common than now.

While classification, in the opinion of some roads, leads to law suits, the writer believes that it saves money by reducing the contractor's risk, a matter that could be accomplished otherwise only by investigations, not always practical.

Is it practicable to make a test upon the materials generally found in excavation for public work? As a first criterion, a simple, measurable test, easily applicable, and defining what should be properly in the "earth" classification, is whether or not the material can be plowed in its natural state by a definite plow pulled by a definite number and weight of stock. Whether this material is moved by scraper, grader, cart, car, wheelbarrow, or steam shovel, what is meant is clearly described, namely a material which a designated plow will produce in shoveling condition. This description excludes from the earth classification some material included in some earth specifications, and includes some material which, in others, is classed as loose rock or as hardpan. As will be seen later, earthy material, not included in the "earth" classification, goes to an intermediate classification, for convenience and other considerations, termed "loose rock."

The reason for placing the earthy material, sometimes included in earth and hardpan classifications, in the loose-rock classification, is the obvious one of similarity of cost. If the material is too wet to be plowed, as in case of swamp muck, quicksands and some gumbos; or is too hard to be plowed, like hardpan, cemented gravel, etc., holding to the proper theory of grouping by rough similarity in cost, no designation by name can properly make it "earth" (in a cost sense) for all appliances, although it might be for some. Additional costly work may be required to get the material loaded or transported. In some cases the cost of unplowable earthy material may approximate and exceed

that of solid rock; but, speaking generally, the cost is somewhat similar to the cost of loose rock, and such material is most fairly included in that classification.

Preliminary to the consideration of a physical test for solid and loose rock, the following definitions have been abstracted from current specifications:

Solid Rock

New York, New Haven and Hartford.—"All rock or stone containing one cubic yard or more." (All other material is earth.)

Erie.—"Rock in masses exceeding one cubic yard, which cannot be removed without blasting."

Pennsylvania.—"Rock in masses exceeding one cubic yard, which cannot be removed without blasting."

Baltimore and Ohio.—"Rock in solid beds or masses, which may be best removed by blasting."

Chesapeake and Ohio.—"Rock in ledges and detached masses exceeding one-half cubic yard, which may best be removed by blasting."

Norfolk and Western.—"Rock in masses which may best be removed by blasting."

Southern.—"Rock in masses of more than one cubic yard, which may be best removed by blasting."

"Big Four."—"Stone in solid masses or ledges."

Chicago, Burlington and Quincy.—"Stratified rock weighing more than 140 lb. per cubic foot, which can only be removed by blasting."

Chicago and Alton.—"All stratified rock and rock occurring in masses which can only be removed by blasting . . . must ring under hammer."

Great Northern.—"Rock in place, in removing which it is necessary to resort to drilling and blasting."

Atchison, Topeka and Santa Fé.—"Rock in solid beds or masses in its original or stratified position . . . other material which can be removed without continuous drilling and blasting, but which is as difficult . . . as solid lime or sandstone."

Illinois Central.—"Rock in solid beds or masses in its original position . . . which may best be removed by blasting." (Everything else classed as "common excavation.")

Northern Pacific.—"All rock in masses that cannot be removed without drilling and blasting."

Missouri Pacific.—"Rock in solid beds or masses, in its original position, which can only be removed by continuous blasting."

What is "rock" and "stone"? Notice the following definitions:

Standard Dictionary.— *Rock*.—"The consolidated material forming the crust of the earth. . . not excluding beds of clay or sand . . . a rock may consist of one mineral species, as limestone, or of several intermingled, as granite . . . massive rock, a rock that does not exhibit foliation or schistose structure."

Stone.—"A small piece of rock. Rock as a material, a piece of rock shaped for a specific purpose. Synonyms, boulders, cobble, mineral, gem, pebble."

Century Dictionary.— *Rock*.—"The mass of mineral matter of which the earth, so far as accessible to observation, is made up; a mass, fragment or piece of the crust, if too large to be designated as a stone. The unconsolidated stony materials which form a considerable part of the superficial crust, such as sand, gravel and clay, are not commonly designated as rock or rocks; the geologist . . . includes under the term rock . . . all of the consolidated materials forming the crust, as well as the fragmental or detrital beds which have been derived from it."

Stone.—"A piece of rock. The name rock is given to the aggregation of mineral matter of which the earth's crust is made up. A small piece or fragment of this rock is generally called a stone."

Webster's Dictionary.— *Rock*.—"Any natural deposit forming part of the earth's crust, whether consolidated or not."

Stone.—"Concreted, earthy or mineral matter . . . also any particular mass of such matter. In popular language, very large masses of stone are called rocks; small masses are called stones; and finer kinds, gravel or sand."

Gillette's "Rock Excavation."—"Rocks are aggregates of one or more minerals, or the disintegrated products of minerals."

These definitions do not help to clear up any uncertainties there may be in railroad classifications.

Loose Rock

Erie.—"Slate, shale or other rock which can properly be removed by steam shovel, pick or bar, without blasting, although blasting may be resorted to on favorable occasions to facilitate the work . . . detached masses, 3 cu. ft. to 1 cu. yd."

Pennsylvania.—"Stone and detached rock lying in separate and continuous masses containing not over one cubic yard; also

all slate or other rock that can be quarried without blasting, although blasting may be occasionally resorted to."

Baltimore and Ohio.—" Slate, coal, shale, soft friable sandstone and soapstone, detached masses 3 cu. ft. to 1 cu. yd."

Chesapeake and Ohio.—" Shale, slate, ochre, which can be removed with pick and bar, and is soft and loose enough to be removed without blasting, although blasting may be occasionally resorted to. Detached masses 3 cu. ft. to 1 cu. yd."

Southern.—" Soapstone, shale and other rock which can be removed by pick and bar and is soft and loose enough to be removed without blasting, although blasting may be occasionally resorted to. Detached stone 1 cu. ft. to 1 cu. yd."

Norfolk and Western.—" Shale, soapstone, and other rock which can be removed by pick and bar, and is soft and loose enough to be removed without blasting, although blasting may be occasionally resorted to. Detached masses 1 cu. ft. to 1 cu. yd."

" Big Four."—" Shale, coal, slate, soft sandstone, soapstone, conglomerate stratified limestone in layers less than 6 in.— detached masses 3 cu. ft. to 1 cu. yd."

Chicago, Burlington and Quincy.—" Stratified rock which can be removed by pick and bar weighing more than 140 lb. per cu. ft. Detached masses 3 cu. ft. to 1 cu. yd."

Chicago and Alton.—" Stratified rock which can be removed by pick and bar . . . and masses between 3 cu. ft. and 1 cu. yd."

Great Northern.—" Slate and other rock, and loose enough to be removed without blasting, although blasting may be occasionally resorted to. Detached stone 3 cu. ft. to 1 cu. yd.

Atchison, Topeka and Santa Fé.—" Hard shale or soapstone . . . in original or stratified position, boulders in gravel, cemented gravel, hardpan . . . and other material requiring . . . use of pick and bar or which cannot be plowed with 10-in. plow and 6-horse team."

Illinois Central.—(No loose rock. Everything but solid rock classed as common excavation.)

Northern Pacific.—" Slate, soft sandstones, or other rock that can be . . . removed without blasting . . . detached rock between 1 cu. ft. and 1 cu. yd."

Missouri Pacific.—" All rock . . . which requires for its removal steam shovel or pick and bar, without blasting, although blasting may be resorted to at the option of the contractor. Detached masses 1 to 18 cu. ft."

A composite view of the several descriptions of rock and loose rock would reduce to about this: Rocky material which can be removed without blasting is loose rock; and that which cannot is

solid rock. That word "can" is the whole of the question, the uncertainty of the answer to which causes most of the disputes about classification.

Taking a general view, the difference between materials in a construction sense is obtained by the writer from consideration of the operations necessary in loading such material. Earth is a material which can be reduced to loading condition by plowing or equivalent inexpensive picking or blasting. Loose rock is a material which generally can be put into handling shape by picking, barring and light sledging, or, in lieu thereof, by moderate blasting, but it is not quite as easy to load as earth. Solid rock is a more refractory material, requiring drilling, strong explosives, and general sledging; and, with this additional expense, is not capable of reduction to a loading condition as favorable as the other materials.

Can a physical uniform test be applied? It is known that certain soft or fractured rocks can be picked or barred apart with reasonable rapidity, and customary specifications state the fact, but do not state the rate. By definition of that rate the classifications of rock can be clearly defined. The writer thinks that, keeping close to current practice in classification, the rate of disintegration for loose rock should be within the performance of two men thus employed. A material requiring more than two men working with pick and bar to keep one shoveler busy is certainly a material that "may better be removed by blasting" and which "can only be removed by blasting," in a reasonable sense.

A consideration of importance is the size of the rocky mass that must be exceeded in order to constitute a solid-rock classification. In hand-work an isolated mass of 3 cu. ft. can be handled without much difficulty; but any larger mass will require disintegration before loading. The expense of this disintegration per cu. yd. will be higher than that for disintegrating masses of the same material which, under any size limit, would still be solid rock. In steam-shovel work very considerable masses can be loaded without disintegration, and, consequently, without much real extra expense. An objection to a small size limit would be an apparent necessity for more particularity of measurement. As to that, the separate quantities in mixed material, in practice, are approximated percentages, and are as easy to calculate with one size limit as another. Bearing in mind the theory of trying to fix classification by similarity of cost, the writer thinks that 1 cu. yd.— the limit most frequently specified — is too high; 3 cu. ft., although right in one view, is probably too low; and that the compromise limit of ½ cu. yd. would be about right. This limit was formerly common, and is still retained in some specifications.

In an endeavor to set forth the foregoing more clearly, Mr. Dennis proposes the following as an outline classification:

Excavation, excepting foundation pits for structures, elsewhere classified separately as foundation excavation, shall be either classified or unclassified, as may be determined at the time of the contract. If classified, the following classification shall apply:

Earth.— Material which in its customary natural condition can be plowed — or is equivalent to a material which can be plowed — with a plow cutting a furrow 10 in. wide and 10 in. deep, drawn by a team of 4 horses, or mules, each having an average weight of 1,100 lb., and moving at a reasonable plowing speed, shall be classified as earth.

Loose Rock.— The following shall be classified as loose rock: Earthy or mixed materials, not susceptible of plowing under the foregoing test; soft, fractured, disintegrated or other rocky material, soft or loose enough in its natural condition to be barred or picked apart by two men thus employed serving one man shoveling or loading by hand; solid rock in separate masses exceeding 1 cu. ft. each, and not exceeding ½ cu. yd. The continuous or occasional use of explosives, at the contractor's option, shall not affect the classification, but it shall be governed solely by the test above set forth.

Solid Rock.— The following shall be classified as solid rock: Rocky material in masses exceeding ½ cu. yd., which cannot be broken apart, or displaced from its natural position, except by the use of explosives; and other rocky material which cannot be picked or barred apart by two men thus employed serving one man shoveling or loading by hand.

Where any excavation contains material of more than one classification, the relative percentage of each shall be determined by measurement and observation during the progress of the work.

For heavy steam-shovel work, Mr. Dennis' opinion is that there is no especial benefit in a distinction by classification between loose rock and earth, and, for that class of work, a classification for solid rock and another for all other material would be sufficient; but nearly all steam-shovel work involves more or less miscellaneous accessory work for team and hand appliances, and the loose-rock classification is needful for them; furthermore, classification on all work would become better established by its uniform practice.

Excavation for foundations of pipes, masonry, or other structures, shall be classified as foundation excavation under the following heads:

Dry-Foundation Excavation. Material of whatever nature, excepting solid rock, found above water level;

Rock-Foundation Excavation. Material, elsewhere defined as solid rock, found above water level;

Wet-Foundation Excavation. All material below water level.

By "water level" is meant the average or mean level during construction at which pumping or bailing becomes necessary in the work of excavating. The quantity of wet excavating shall be computed as a prism having a height equal to the distance between the average level of the bottom of the foundation pit and the water level and a base equal to the area of the foundation course plus 4 ft. all around. The dry and rock excavation quantities shall be computed on a base equal to the bottom area of the wet excavation as above defined, with the necessary slopes to the natural surface.

Wet excavation shall include the cost of excavating, piling, coffer-dams, pumping, bailing, leveling off the bottom, and the expense, of whatever nature, necessary to complete the foundation pit from low-water level to the level finally determined for the bottom, and to maintain the foundation pit open until the structure shall have been placed therein, not, however, including the placing of iron, timber, or piles, in permanent artificial foundations, these items being paid for under a separate schedule elsewhere described.

The prices for all classes of foundation excavation shall include the cost of removing the spoil, and depositing it in adjoining fills, or of wasting the spoil, if such deposit in fills be not required by the engineer; and also the cost of removing such portions of coffer-dams as the engineer may require, for appearance or for reducing obstruction to the waterway.

Mr. Dennis' paper brought forth much discussion in which it is interesting to note that most of those who favored a classification had one of their own to propose. The following discussion was contributed by the author of this work:

It would be difficult to select any work so hard to define in words, as the classes of excavation. Earth merges by insensible degrees into hardpan or shale; hardpan and shale merge into conglomerate and slate by equally insensible degrees; geologically, there is no dividing line between what is called "earth" and what is called "rock." This fact is well illustrated in the dictionary definitions cited by the author, and it is shown even better by the definitions found in textbooks on geology.

It may be seen, therefore, that some arbitrary test should be prescribed to differentiate rock from earth when different prices are to be paid for each. The ancient "plow test" has many adherents, but in its usual form it is probably more productive of legal trouble than any other clause ever devised by an en-

gineer. Some years ago the State Engineer of New York suffered most unjust criticism because of supposedly unfair classification of excavation by the plow test, and his retirement from office was probably due in large measure to this unjust criticism.

The writer, while on the editorial staff of *Engineering News* in 1903, wrote a series of editorial articles criticizing specifications, and he recalls having written one suggesting an earth classification test somewhat similar to that proposed by Mr. Dennis. Instead of specifying a furrow 10 by 10 in., however, he suggested a minimum number of cu. yd. loosened per 10-hr. day by a 6-horse plow. It still seems to the writer to be a much better plan to specify in cubic yards, for the cubic yard is the unit of cost, and, after all, the object is to secure some definite cost classification. A 10 by 10-in. furrow cut by four horses means nothing very definite unless the amount of useful work is specified, either by naming the average speed of cutting, or the average number of cu. yd. to be loosened in a given time: but why limit "earth" to such easy material as can be loosened by four horses? Ten-horse plows are very common in the West, where driving with a jerk-line is practiced. There is a serious objection to the plow test wherever work is to be done with steam shovels, and the objection is that it is practically impossible to apply the test in many cases. In a through cut, for example, the top 4 ft. of material may be loam, below which may lie an indurated clay of hardpan consistency. The steam shovel exposes a vertical face upon which no plow test can be made; unless this 4-ft. stratum is stripped, the plow test is of no use on the surface. The bottom of the pit may be solid rock. Of what practical use is the plow test under such conditions?

Many other conditions might be mentioned to show the exceeding difficulty of applying a plow test in a satisfactory manner. One more will suffice. In soil of glacial origin, lenses of hardpan are frequently encountered, surrounded by gravel, sand, or shot clay. It is impracticable to strip these lenses in steam-shovel work for the purpose of using a plow test, and, without stripping, no such test is possible.

The plow test, therefore, may serve in plow work, but it is practically useless in much of the work done by steam shovels.

What test, then, shall be applied? In the writer's book on earthwork, the suggestion is made that excavation be classified by samples taken from specified locations on the profile. No practical method of specifying with any degree of exactitude seems possible to the writer, and a varied experience, embracing excavation at different places across the American continent, has served to emphasize this conclusion.

It is true that this method of "specifying by samples" involves digging test-pits and sinking bore-holes, but the writer is firmly convinced that no engineer ever spent a dollar that returned a greater dividend than the one spent in ascertaining the character of the excavation before the award of the contract.

On any extensive piece of excavation, earth should be dug, and rock should be blasted, by the engineer, to ascertain its quality, as well as to determine the relative quantities of each class. The engineer who cannot persuade his employer to go to this extra expense is hardly fit to be in charge of the work; or, if he is fit, he does himself an injustice in not resigning if his advice is ignored.

The American Railway Engineering and Maintenance of Way Association Classification as given in the Manual for 1915 is as follows:

Classification.

17. All material excavated shall be classified as "Solid Rock," "Loose Rock," "Common Excavation," and such additional classifications of material as may be established before the award of the contract.

18. "Solid Rock" shall comprise rock in solid beds or masses in its original position which may be best removed by blasting; and boulders or detached rock measuring one cubic yard or over.

19. "Loose Rock" shall comprise all detached masses of rock or stone of more than one cubic foot and less than one cubic yard, and all other rock which can be properly removed by pick and bar and without blasting; although steam shovel or blasting may be resorted to on favorable occasions in order to facilitate the work.

20. "Common Excavation" shall comprise all materials that do not come under the classification of "Solid Rock," "Loose Rock," or such other classifications as may be established beford the award of the contract.

Factors Affecting the Cost of Earthwork. These are many. Not all can be determined beforehand but it is well that they all be kept in mind so that the extent to which an estimate is a guess may be known. Some of the factors are:

1. Location.
2. Climate.
3. Time of year during which work is to be done.
4. The quantity of earth to be moved.
5. The position of the earth to be moved.
6. The amount and nature of clearing and grubbing.
7. The average depth of cut.

8. The kind of earth.
9. The length of haul.
10. The hauling conditions, including grades.
11. Ground water conditions.
12. The square yards of surface of cut and fill that must be trimmed.
13. The disposition made of excavated material.
14. The method of compacting.
15. Wage rates and prices.
16. The interest rate on money.

Most of these factors cannot be considered independently but their relation to each other must be borne in mind. Thus, the type of excavating equipment used is not only a factor that affects the cost but is itself determined by existing conditions.

Location is of chief importance in respect to its relation to lines of transportation. This is especially true on work involving the use of heavy machinery which away from railroads is moved only at great expense.

The Climate has a greater effect on earthwork costs than is generally recognized. Local contractors know more or less what to expect; and, like farmers, their losses through bad weather one year are made up for by favorable weather in another. A firm taking a single earth work contract or taking one in a strange location should consider the climate most carefully. Extremes of heat and cold slow up outdoor work, and storms stop it all together. Profit or loss may depend on the number of days available for working during the season.

The Time of Year that work is to be done considered in relation to climate and other factors will largely determine the conditions encountered. Muddy roads in the spring, dusty roads in the late summer, and, above all, snow and frozen ground in the winter add to the cost of earthwork.

The Quantity of Earth to be Moved is the chief factor for determining the means to be employed for moving it. It is impossible to state any quantity or range of quantities of excavation as best suited to a particular type of machinery, as it is often more economical to use equipment on hand than to purchase more elaborate machinery.

The Position of the Earth to be moved is shown on the plans. A mass of earth may be under water, and require dredging; or it may be along the slope of a hill where it can be cast down with steam shovels; or it may be through the center of a hill permitting attack from the ends only, as in deep railroad cuts. These conditions not only affect cost but are factors in determining the means of excavation.

The Amount and Nature of Clearing and Grubbing. Costs of clearing are always determined by the area to be cleared and the growth. Grubbing costs on the other hand depend equally on the method of excavation. Deep steam shovel cuts require no grubbing. Scraper work requires grubbing and ground moved with elevating graders must be most carefully grubbed.

Depth of Cut. Material at the bottom of deep cuts is often compacted into a condition hard to excavate. Deep, long cuts permit the use of powerful machinery with a minimum amount of shifting, and are therefore generally cheaper to excavate than shallow cuts.

The Kind of Earth. No earthwork on a new locality can be closely estimated without first digging test pits the full depth of the proposed excavation. The common method of driving a steel bar into the ground is often very deceptive, for it may not disclose the existence of quicksand, or of numerous scattered boulders; and even hardpan may be penetrated with a bar. Test pits are costly to dig and many methods of making borings are resorted to. These usually bring up the material in a thoroughly loosened condition so that its original consolidation can only be judged by the difficulty of boring. Results of wash drilling for this purpose may be very deceptive. At least one test pit should b opened as a means of interpreting every series of test borings.

The Length of Haul is generally shown on the profile of railroad work. On other work it is not so well shown and should be investigated. Beyond a rather short limit a light railway furnishes the cheapest means of haulage, and if it is used the length of haul is of relatively less importance than the ability to load and dump trains rapidly.

Hauling Conditions. Light railways are more easily maintained in muddy weather than wagon roads. Wagons, on the other hand, can operate over steeper grades and greater irregularities. Truck haulage is of greatest advantage where somebody else pays for the roads. Whatever the means of hauling adopted a grade against the movement of material will add materially to the cost.

Ground Water. The presence of water always increases the difficulty and cost of excavation. If cuts are not self-draining means of pumping must usually be provided, and when the work gets below the ground water level pumping must be constant. Excavations in springy hill sides will be hard to handle even if of such a nature as to drain themselves.

Trimming Cuts and Embankments is seldom paid for as a separate item. An estimate based on the number of sq. yd. of

trimming involved should be included in the price bid for excavation.

Disposition of Excavated Material. If material is to be used in an embankment, its disposition is clearly indicated, otherwise dumping space must be provided.

The Compacting of Embankments for railroads and levees is usually left to nature. For structures requiring artificial consolidation the method to be used is specified in detail. Usually water is required and will have to be carried to the work. The cost involves not only spreading, wetting and rolling, but dumping in thin layers will be more expensive than dumping haphazard.

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CHAPTER III

BORING AND SOUNDING

Prospecting or Testing Earth. It is usually advisable to make an "underground survey" of earth that is to be excavated, particularly if it is likely to be variable in character, or if rock, boulders, or hardpan may be encountered. For this purpose the following means may be employed:

1. Soundings.
2. Wash Drilling.
3. Earth Augers.
4. Posthole Diggers.
5. Cable Drills.
6. Diamond Drills.
7. Test Pits.
8. Test Trenches.

Soundings. The word sounding is used to designate the driving of a rod into the earth, the object being to ascertain the depth to rock or hardpan or to determine the presence of boulders.

Wash Drilling. Wash drilling consists in sinking a "casing pipe" inside of which is a smaller "wash pipe" through which water is pumped. The water raises the earth to the surface. Where boulders are encountered, small blasts may be fired, or a chopping bit may be used to break up a small boulder.

Earth Augers. Modified wood augers are frequently used to bore holes in earth, either with or without the use of a casing pipe.

Posthole Diggers. For shallow test holes, posthole diggers of various types are available.

Cable Drills. For deep holes, cable drills of the well-drill type are often used. This type of drill is fully described in my "Handbook of Rock Excavation."

Diamond Drills. Where there are many boulders or where it is desired to obtain cores of the bed rock, diamond drills are often used, as described in my "Handbook of Rock Excavation."

Test Pits. Test pits are small wells dug to ascertain the character of the earth.

Test Trenches. These are more often used in prospecting for mineral ledges than for testing the character of earth to be excavated. It is well, however, to bear in mind that on sidehill work trenches can be frequently excavated very cheaply by the use of hydraulic "giants."

Importance of Prospecting Excavations. Considering the rela-

tively slight cost of testing the character of earth, it is surprising how seldom underground surveys are made. Engineers have been too much given to guessing at the percentages of each class of excavation. Seldom has the cost of extensive railway or canal work been correctly estimated, because of erroneous assumptions as to the character of the excavation. Almost microscopic care has usually be exercised in ascertaining the total quantity to be dug, but with next to no attention given to the exceedingly important fact of *quality* to be dug.

Sounding is a cheap and rapid method of prospecting for rock or hardpan. A rod or pipe may be driven to depths of 20 or 30 ft. with a maul or drop weight. If varying materials are encountered, sounding may be extremely unreliable as a stratum of hard sand or gravel may be mistaken for solid rock. The usual manner of testing for this is by striking the rod a smart blow with a hammer. If its end is on solid rock the rod should rebound and should ring with a clear metallic tone, whereas on gravel or hard pan it will not rebound and will not give a clear ring. The presence of a boulder may cause this test to be deceptive.

A Jointed Sounding Rod. M. L. Hastings in *Engineering News*, June 29, 1889, described the sounding rod illustrated in Fig. 1. The rod itself is made of seamless cold-drawn steel

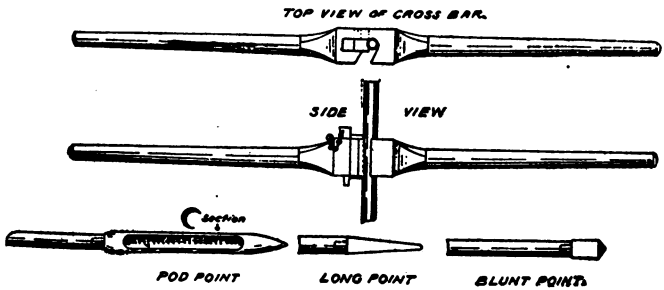


Fig. 1. Jointed Sounding Rod.

tubing, $\frac{3}{4}$ in. in exterior diameter, $\frac{1}{8}$ in. thick in section, and 8 ft. long. The sections are joined and plugged with a steel plug with thread cut to screw into the end of other sections. The advantages of this type of joint is that a smooth outside surface is obtained throughout the length of the rod. The rod has three points: (1) The blunt one for testing the bottom; (2) the long one for going through crust, etc.; and (3) the pod point for

bringing up samples. The cross-bar is attached to the rod by means of a movable block of hardened steel on the face of which (next to the rod) are cut teeth, the block being held in place by a wedge attached to the bar with a small chain. The movable block is kept from falling by a pin in the back of the cross-bar.

A Square Sounding Rod. W. L. Goodhue, in *Engineering News*, May 11, 1889, describes an effective boring outfit shown in Fig. 2. This apparatus cost about $25 and was easily constructed. It could bore through earth to depths of 28 to 30 ft.

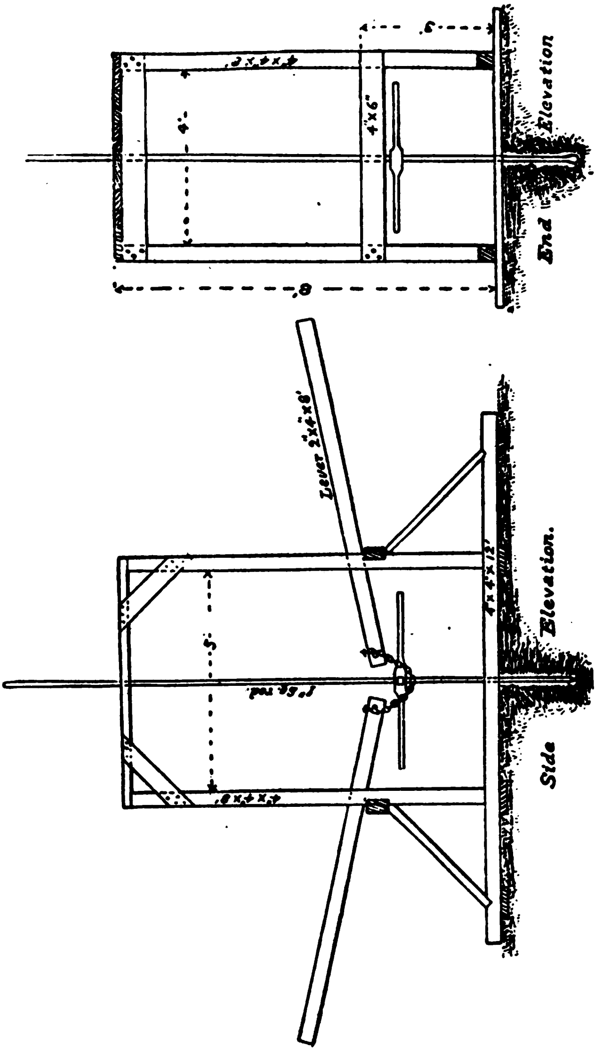
The drill was formed from a 1-in. square iron rod, with a chisel-shape bit about 3/8 in. wider than the rod. A square rod penetrated more easily than a round rod and was more readily raised. The upper half of the rod was drilled with a 3/8-in. hole every 20 in. Through this hole an iron pin, about 3 in. long, with an eye on one end, was inserted for holding the lifting chain. The iron cross-bar was made of bar-iron 1¼ in. square, 4 ft. long. It was reinforced with 1 in. of iron at the eye through which the drill rod passed. One side of the eye was tapped for a ¾-in. set-screw which held the cross-bar to the rod. The rod was lifted and forced down by men on the ground, assisted, if necessary, by other men on the timber platform; a total of 3 men being employed. When difficulty was experienced in lifting the rod the levers illustrated were used. Plenty of water was used for puddling the hole.

A Light Pile Driver. For sounding the thickness of earth over rock on the Welland Canal a pile driver is described in *Engineering News*, Apr. 8, 1915.

The pile driver was about 25 ft. high and weighed about 200 lb., so that it was easily portable by two or three men. It carried a 135-lb. hammer operated by hand through a single line over a sheave at the top of the leads. A bar 3 in. in diameter, shown in Fig. 3, with an upset head and tenon joint into which a driving point was fitted, was driven to rock. A new driving point, at a cost of 2 ct., was provided for each operation, the old one being left in the hole. For pulling the bar a clamp in the shape of a bifurcated cone was fitted under the head of the bar and the pile driver rope slung around the clamp to the bar and lifted the bar at the same time.

This rig was used extensively on the Welland Canal to locate the rock surface, and later was used in Nova Scotia where it worked ahead of a steam shovel, making blast holes for small shots to break up a shaly formation.

Samples of the Material Penetrated may be secured by driv-



A Cheap and Effective Test Boring Outfit.

Fig. 2. A Square Sounding Rod.

ing or screwing a hollow tube into the bottom of the hole. An open ended pipe provided at the end with sharp teeth, may be twisted into the material, and then withdrawn, carrying with it a sample in the form of a plug filling the hollow of the pipe. The R. G. Hunt & Co. sampler for marl is illustrated in Fig. 4. This tool is forced down the depth desired and then turned half-way around, filling it with a sample of the material. The

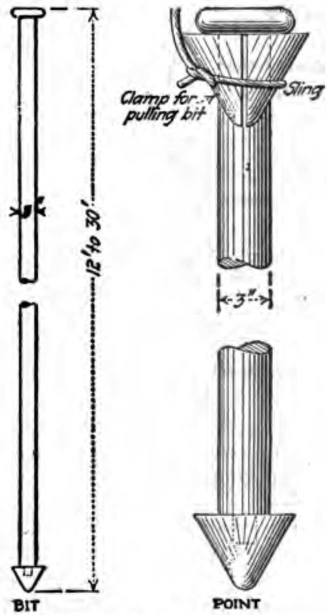


Fig. 3. Bar and Attachments for Rock Sounding Pile Driver.

Michigan Geological Survey Marl sampler, illustrated in Fig. 5, is used for obtaining samples of material in a semi-liquid state. In operation, the plug is held firmly against the mouth of the pipe by means of the rod and the whole tool is pushed the desired depth. The pipe is then raised while the rod is held stationary, and is pushed down to its former position. The whole tool is then raised, the plug and pipe being held tightly together.

A Soil Sampler. A device designed by R. R. Ryan is shown

in Fig. 6, which is taken from *Engineering and Contracting*, Nov. 21, 1917. The device consists of an outer section, composed of 6-in. light weight well casing, which is forced down by a weighted platform. The inner section is made of 5-in. light weight well casing and carries the cutter. The two sizes of casing rest snugly but not tightly so that the barrel moves

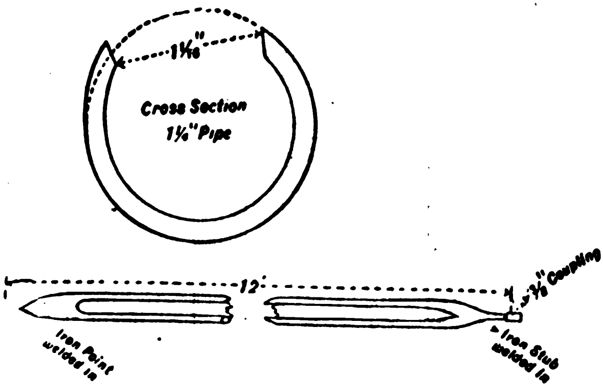


Fig. 4. Sampler for Marl Made by Robert G. Hunt & Co., Chicago, Ill.

freely within the outer case. The arrangement was first used in 1909 in bringing up samples of the soil at the site of Florence Bridge, Florence, Ariz.

Wash Borings. These can be made to depths beyond the reach of sounding. Like soundings they may be deceptive. The ma-

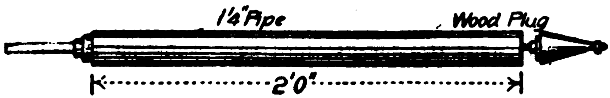


Fig. 5. Sampler for Liquid Marl; Michigan Geological Survey.

terial washed up will show whether the bit is working in clay or gravel, but it is so broken up and mixed with water that it does not indicate the compactness of the underlying material. Boulders can be mistaken for ledge rock, and any fine sand for quicksand.

In general the wash drill consists of a small pipe contained

in a larger pipe. The inner pipe is used for carrying water under pressure down into the hole where it loosens material which is washed up and out of the larger pipe. The outlet pipe is lowered as the inner one progresses, at an interval depending on the material. Sand and gravel, being apt to cave, require that the outer pipe be kept close, whereas considerable advance can be made in clay without casing.

Although it is customary to use a 2-in. casing pipe with a 1-in. water pipe inside, a 4-in. casing and a ¾-in. water pipe (not contracted at the bottom) may be preferable where large gravel must be washed out of the hole. If gravel is so large

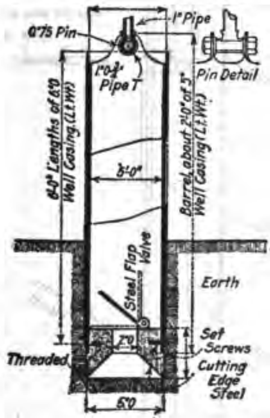


Fig. 6. Half Section of Soil Sampler.

that it will not pass between the water pipe and the casing, two expedients are available. The gravel may be broken up or pushed aside with a heavy, blunt drill, or one with a star-cutting bit, which can be lifted with a block and fall suspended from a light tripod. The other method consists in using a "sand pump" or "pipe bucket" with a valve at its bottom. Lifting and dropping a sand pump with short, quick strokes, will fill it with material not too large to pass its valve.

Tests made by boring holes require careful observation and intelligent interpretation if they are to prove reliable. In wash borings, especially when the water used is under great pressure, the natural tendency is to indicate coarser material than is really encountered, because the fine material is carried off, and the greater portion of the particles remaining in the sample pail

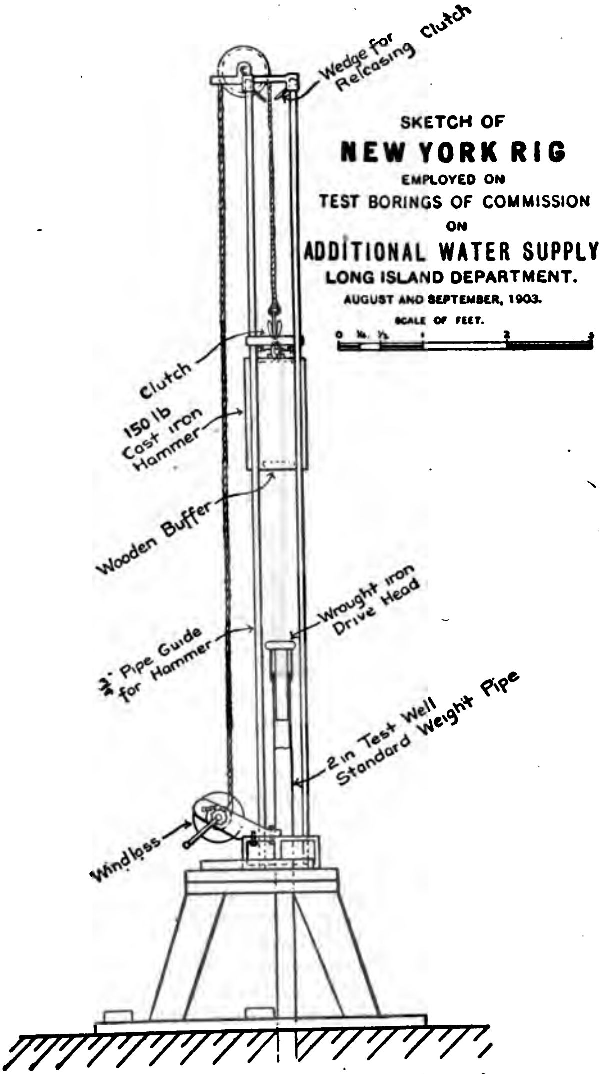


Fig. 7. New York Wash Boring Rig.

are large in size. Clay and silt appear to be sand and sand appears to be gravel. To remedy this, dry samples should be taken occasionally, and the discharge pipe should be covered with bagging in order to catch as much of the finer material as possible.

In the report of the Commission on Additional Water Supplies for the City of New York, rendered in 1903, by Messrs. Burr, Herring and Freeman, are given descriptions and illustrations of hand-operated wash-boring machines used for driving test holes. There were four types of rigs used: (1) the New York rig; (2) the Boston rig; (3) the Providence rig; (4) a rig designed by the Commission.

The New York rig is illustrated in Fig. 7 and is the outfit commonly employed about New York by the Brooklyn water department for driving 2-in. service and test holes. The essential features are a heavy wooden base about 2 ft. high, 4 hammer guide-rods erected on this base, a cast iron head which holds the guide rods, and a small lead rope wheel through which the lead from the hammer passes to a handle with two cranks. The hammer weighs about 150 lb. and is automatically tripped. The maximum drop is 8½ ft. A ¾-in. wash pipe and an inexpensive 2½-in. force pump with a delivery of 8 to 10 gal. of water per min. are commonly used for this machine. This size pump does not deliver water at sufficient pressure to wash up gravel larger than peas, however. This rig does not permit continuous washing and driving, the wash pipe being advanced several feet below the bottom of the casing, but it usually washes holes larger than the casing and will permit more rapid progress than will the other rigs. It does not produce samples as accurate, however.

The Boston rig is shown in Fig. 8. In general it consists of a hollow cast steel driving head, 2½-in. casing with 1½-in. side discharge, and 2 hammers of 100 and 200 lb. weight, a wash pipe of 1-in. section and special wash drills, and a double-acting force pump, with a 1½-in. suction hose and a 1-in. discharge hose. A force of four men (one foreman and three laborers) was required, in addition to the driver of the water wagon; two men worked on the hammer, one on the pump and one on the wash pipe and handling the water.

The Providence rig like the Boston rig is of the continuous wash type but the method of operating the hammer is essentially different, as will be seen from Fig. 9. The hammer is raised and dropped by men working on a platform. The pump successfully used with this type was similar to those used on the Boston rig. The weight of the men of the platform was of little value

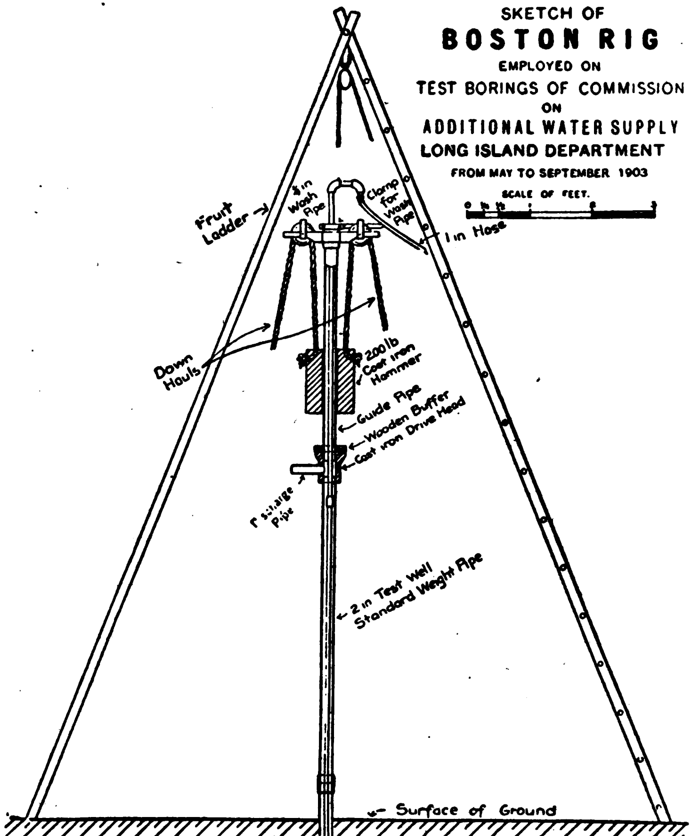


Fig. 8. Boston Wash Boring Rig.

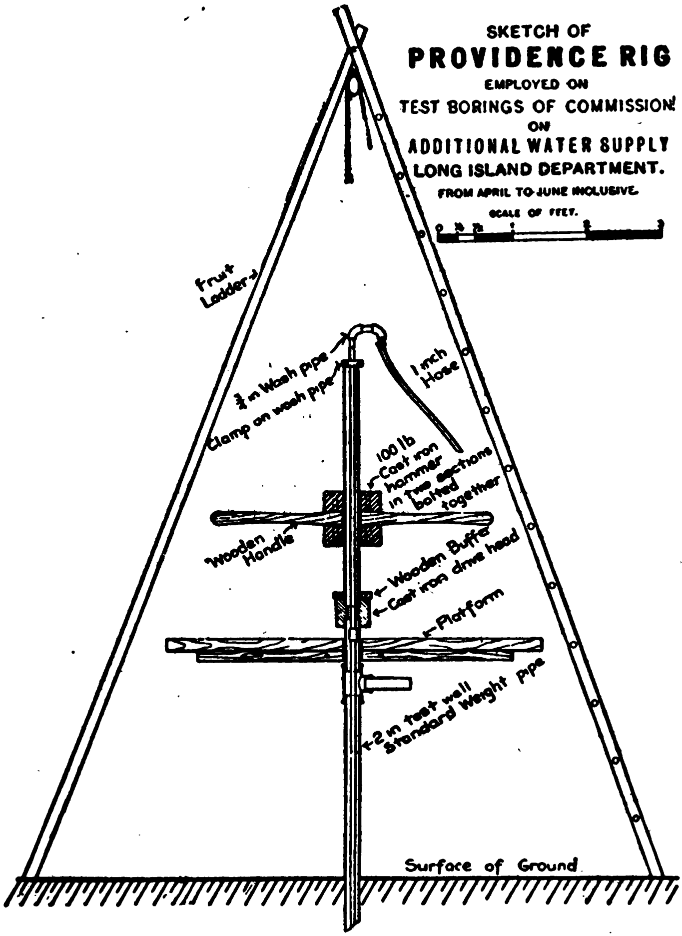


Fig. 9. Providence Wash Boring Rig.

in lowering the casing and made it difficult to keep the casing in a vertical position. The same crew was required as for the Boston rig.

The rig finally adapted by the commission is illustrated in Fig. 10. This was patterned after the Boston rig. The yoke and small pulleys were replaced by 2 large gin wheels suspended at the peak of a 12-ft. pipe derrick. With this rig it was possible to secure dry samples by driving a 1¼-in. pipe 3 or 4 ft. into the material at the bottom of the casing. A force of 4 men and 1 driver was employed with this rig. The cost of the rig complete was about $150.

Altogether 332 test holes (2-in.) were driven a distance of 11,605 ft. The total cost of the work is shown in Table I. In the loose gravels of the Southshore of Long Island boring cost about 60 ct. per ft., but in the compacted till on the northernly portion where dynamite was used the cost ran up to $2 per ft. or more. This work was more costly than the average work, for it is not generally customary to place more than one engineering inspector on several outfits. Moreover, casings are usually pulled and the pipes used repeatedly, and water can ordinarily be piped from a town's supply. The cost of labor was $1.75 per day except during the first few weeks. After deducting 15 ct. per ft. from the item of inspection, 10 ct. per ft. from that of teams, and 10 ct. per ft. from cost of pipe, the total cost reduces to 85 ct. per ft. which is probably nearer the usual cost of such work.

TABLE I. COST OF LONG ISLAND WASH BORING

Item	Total cost	Cost per ft. of pipe driven (11,605 ft.)
Superintendence, inspection, engineering	$ 2,815	$0.243
Labor: foremen, $3 and $3.50 per day; laborers, $1.50 and $1.75	5,074	0.437
Teams: $3 and $3.50 per day	1,612	0.139
Transportation, fares, livery, freight, express	560	0.048
Cost and rental of boring rigs	619	0.053
Two-in. pipe, perforated pipe, points	1,724	0.149
Misc. expenses, sample bottles, cases, blasting, etc.	315	0.027
Totals	$12,719	$1.096

Wash Borings, New York State Canal were made along the possible routes of a proposed ship canal in New York between the Great Lakes and the Hudson River, as described in *Engineering and Contracting*, Mar. 27, 1907. A very complete abstract of that article is given in my "Handbook of Cost Data."

Cost of Well Drill Borings at Stanley Lake. I am indebted to

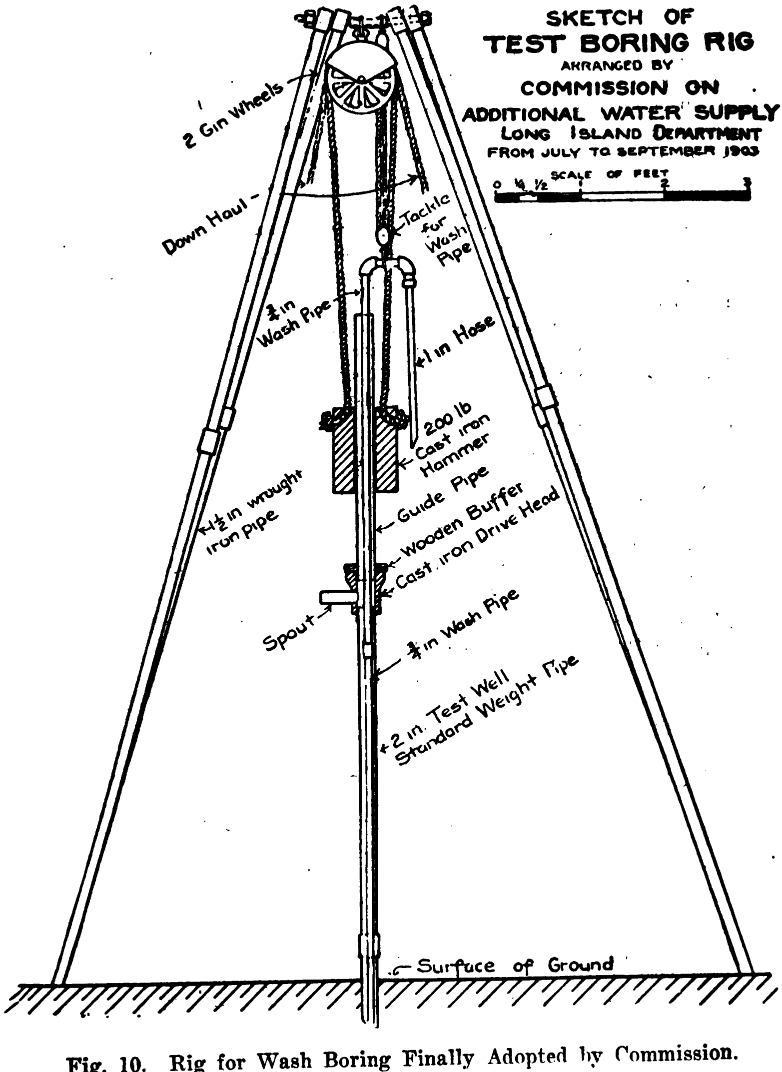


Fig. 10. Rig for Wash Boring Finally Adopted by Commission.

a report by M. E. Witham published in *Engineering Record*, Nov. 27, 1909, for the following data of the method and cost of making wash drill borings for the Stanley Lake Dam near Denver, Colorado. This dam had a length at the crest of 9,140 ft. and a test hole was sunk every 200 ft. on the axis of the dam, and at intervals of 100 ft. on the line of the outlet structure under the dam to depths of from 20 to 80 ft. The site of the borrow pits from which material was to be taken was also bored.

The drill used, of the spudding type, was a No. 4, 8-hp., combination hollow-rod Cyclone machine, mounted on a 4-wheeled truck. Holes 2½ in. in diameter were drilled with 1½-in. hollow-rods having a center bore of ½ in.

The operating force consisted of a drill runner, a fireman, and a sample collector. Coal and water were delivered by team. Coal cost $3 per ton at a mine 7 mi. distant. The water was brought from adjacent irrigating ditches. The drill runner received $5 per day and board, the fireman $2, the sample collector $3, and the team and driver regularly employed $4. Extra teams and drivers cost at the rate of 80 ct. per day for the entire time occupied by the work. The first 9 days were occupied largely in putting the drill in proper shape. The average time consumed in taking down the drill, moving 200 ft. and setting up was 2 hr. and cost about $3. In satisfactory material drilling cost 30 ct. per ft. of hole; about 10 ft. of hole per hr. was drilled. In troublesome material where casing was required the cost was 60 ct. per ft.

Maximum Cost Hole:

	Depth, ft.
Surface clay, mixed sand and gravel	5.5
Yellow mud	10.2
Yellow clay	24.0
Blue clay	32.0
" " (hard)	47.9
" " (soft)	48.9
" " (fine)	65.0
" " (light)	71.6
" " (hard)	72.4
" " (soft)	83.5
Total depth reached	90.0

Expenses:

Salaries	$58.60
Board	6.00
Coal	2.10
Cost of 90 ft. at $0.74	$66.70

Minimum Cost Hole:

	Depth, ft.
Surface clay and sandy yellow clay	6.0
Mixed blue and yellow clay	19.0

	Depth, ft.
Blue clay (hard)	40.0
Total depth reached	60.0

Expenses:	
Salaries	$13.50
Board	1.50
Coal	1.00
Cost of 60 ft. at $0.27	$16.00
Total for 2,481 ft. drilled:	
Salaries	$ 567,00
Board	133.20
Coal	62.25
Teams	330.00
Repairs, supplies, etc.	50.00
	$1,142.45
	68.50
Total, 2,481 ft. at $0.43	$1,073.95

Cost of Borings at Cristobal, Panama. E. B. Karnopp gives the following information in *Engineering* News, June 16, 1910.

Wash drill and diamond drill borings were made to determine the material beneath a proposed dock for the Panama Railroad at Cristobal. The pipe used in earth consisted of a line of casing 2½ in. in diameter, in the interior of which was a line of hollow rod 1⅞ in. in diameter. A tripod derriek drum and wheel attachment was employed for hoisting the pipe. The tripod was of 2 x 4 in. and 4 x 4-in. timber, and was 18 ft. high. Six men were able to carry it when folded. The casing was made in 5-ft. lengths with flush joints, the first section having a flaring toothed cutting edge. In sinking, this pipe was revolved with chain tongs, and was assisted occasionally in its descent by an iron jar weight of 100 lb. The hollow rods were 5 and 10 ft. in length, the lowest one being fitted with a chopping bit and the top one with a water swivel. In work where the wash drill process was too slow to be economical, a hand-power diamond drill was used. For details of diamond drill outfits and the method and cost of their operation see my "Handbook of Rock Excavation."

For boring holes under water a staging was erected on piles. Water was obtained from the city mains. Boring operation occupied 7 months, and over a length more than a mile 235 holes were drilled.

The equipment comprised 3 drills, each operated by a white foreman and 6 negro laborers. Pipe laying, staging-building, the handling of material, and all surveying work was done by an extra gang of 6 to 10 laborers. Foremen received $150

gold per month and laborers 13 to 18 ct. United States currency per hr. A recorder and draftsman were also employed.

The following table gives the total cost and the amount of work done.

15,183.1 ft. of earth borings, at $0.587 per ft.	$ 8,917.25
1,217 ft. of rock borings, at $2,536 per ft.	3,087.42
16,400.2 ft. Total at average cost $7,319 per ft.	$12,004.67

	Cost per ft. Earth	Rock
Supervision and surcharge	$0.054	$0.227
Foreman	.107	.449
Labor drilling	.147	.616
Extra gang and driver	.124	.520
Drafting and recording	.070	.292
Materials consumed	.065	.349
Repairs	.020	.083
Totals	$0.587	$2.536

Wash Borings, Winnipeg Aqueduct. Douglas L. McLain, in *Engineering and Contracting*, April 7, 1915, gives the following: Wash borings were made for the Intake Site and at the Falcon River Crossing with a "string of tools" which, though complete for the purpose, was not as elaborate as that necessary for deep drilling. The list of equipment with cost of same, given in Table 1, may be used for reference when similar work is contemplated.

TABLE I. LIST AND COST OF EQUIPMENT FOR MAKING WASH BORINGS ON WINNIPEG SHOAL LAKE AQUEDUCT

Quantity and description	Unit price	Cost
50 ft. 2½-in. extra heavy pipe (drive casing) in 5-ft. lengths.	$0.57	$ 28.50
Cutting and threading pipe	....	5.00
50 ft. 1¼-in. heavy pipe, five 4-ft. lengths and six 5-ft. lengths	.25	12.50
Cutting and threading pipe	....	3.30
10 2½-in. couplings	.16	1.60
11 1¼-in. couplings	.08	.88
1 malleable 1¼-in. tee	.16	.16
1 double run 10-in. wooden block	1.85	1.85
60 ft. ¾-in. manila rope, per lb.	.14	1.40
1 hand force pump R. 470 — 30 gal. per minute	7.00	7.00
2 24-in. Stillson wrenches	2,25	4.50
15 ft. 1½-in. discharge hose	.30	4.50
20 ft. 2-in. suction hose	.35	7.00
1 1¼-in. street elbow	.15	.15
1 1½-in. coupling for hose	.30	.30
1 2 x 1½-in. bushing	.10	.10
1 1½-in. short nipple	.10	.10
1 1½ x 2-in. nipple	.10	.10
1 drive weight 7 in. diameter by 15 in. long, 2-in. hole all the way through long dimension, widened to 3½ in. from 4 in below top to top	....	....
3 ft. of ¼-in. flexible wire rope for handle	5.60	5.60

Quantity and description	Unit price	Cost
2 1½-in. chopping bits of drill steel with 1¼-in. theads 8 in. long	$6.00	$ 12.00
6 pairs lumberman's rubbers, two buckles, sizes 10, 11 and 12	1.60	9.60
1 pipe vise to take 2½-in. to 1¼-in. pipe	2.00	2.00
1 2-in. foot valve	.45	.45
1 machinist's hammer	1.10	1.10
2 cold chisels	.35	.70
1 pair jacks, 2 in. by 18 in., with handles	6.80	13.60
Steel spindles for same, per lb.	.10	1.20
2 sleeve couplings, 1¼-in. W. T.	.10	.20
3 sleeve couplings, 2½-in. W. T.	.16	.48
2 1¼-in. nipples, 6 in. long	.06	.12
2 1½-in. to 1¼-in. reducing couplings	.10	.20
2 1½-in. nipples, 6 in. long	.08	.16
6 1-gal. pails	.21	1.26
1 pint machine oil, black	.15	.15
1 2-in. nipple, 6 in. long	.10	.10
1 recovering tap	3.75	3.75
2 sister hooks	2.50	5.00
1 clasp for 2½-in. pipe	2.00	2.00
1 hoisting plug	1.75	1.75
6 couplings for 1¼-in. pipe (extra)	.08	.48
1 ice chisel	3.50	3.50
2 axes, 3½-lb.	1.25	2.50
1 air tight heater	2.10	2.10
1 length stove pipe	.10	.10
3 chain tongs, No. 33 Vulcan	4.50	9.00
2 pairs extra leather (front and back) for piston of Meyer's low-down force pump	.35	1.40
3 logs for tripod	....	....
Delivery from C. P. R. station to site (18 miles)	....	12.10
Total		$171.54

With this equipment, the process of sinking the test holes was very simple and usually was as follows:

The derrick or tripod, consisting of three logs, was set up over the station where a hole was cut through the ice and the depth of water obtained by sounding. After this suitable length of casing was put down; at the same time a hole for the pump suction was made and a fire started in the heater to warm water, which facilitated the thawing of the tools. Then drill rods of the required length with chopping bit on lower end and hoisting water-swivel on upper end connected to derrick-rope and by hose to the force-pump, were put down inside the casing. The position of the bottom of the casing and the drill rods having been noted, the drill rods were churned up and down by means of rope over block attached to tripod. At the same time water was forced down the center of these rods to the outlet in chopping-bit and then up between the rods and the casing. The chopped material brought up by the water jet was noted by the leader in charge of the work. To sink the casing, chain tongs were attached and it was rotated. This rotation or turning of the casing to keep it free from sticking to the material

drilled through, was the detail that added most to the speed of work, not only in sinking the casing, but more especially in the pulling of the pipe. This method of sinking the casing was not practical at all times and in such cases the drive weight was used to pound the casing down. After it had been used it was necessary to use two jacks to draw the pipe. As the hole was sunk either by rotation of casing, or driving, constant watch was kept of the position of the bottom of the casing and the drill rods, together with careful note of the materials brought up by the water jet. For this particular piece of work at Indian Bay it was found advantageous to use a force of one leader or foreman and four laborers.

The progress that can be made under winter conditions and the cost of same is given in Table II. This gives total and average figures on the footage, the materials encountered and the labor and food costs and should be of use for information when similar work is contemplated. The force on this work usually consisted of 1 topographer at $3.95 and 3 laborers at $2.55 each, or 1 foreman at $2.80 and 4 laborers at $2.70. The work was done, with the exception of one day in December, between Jan. 9 to Feb. 27, 1914. The thickness of ice ranged fairly gradually from 1.46 ft. on Jan. 9 to 2.60 on Feb. 9. On that day the temperature dropped to —35° and work was discontinued until Feb. 24, when the temperature was +5° at 7 A. M. and the thickness of ice was 3.17 ft.

TABLE II. WASH BORINGS AVERAGE COST DATA FOR WINNIPEG AQUEDUCT

Depth of —	Totals	Average
Water	523.0	......
Muck	45.3	......
Clay	594.2	......
Sand	73.7	......
Gravel	31.7	......
Depth of material bored	744.9	27.6
Total length of casing, includes ice, water and material	1,267.9	47.0
Labor and food cost	$404.75	$15.00
Cost per ft. below lake bottom		$0.541
Total cost per ft. of casing in ice, water, material		$0.319

Wash Borings for Railway Valuation Work. George H. Burgess, in *Engineering News-Record,* April 5, 1917, gives the following: Like other roads the Delaware and Hudson has sections — along the shores of Lake Champlain, for example — where there has been much subsidence. The records showed much of this, but were incomplete. Wash borings were resorted to, and the company profited more or less by the experiences of other roads that faced the problem sooner. Bids were asked

for, but they contained so many conditions that the company decided to do the work by company forces.

Two simple outfits were made in the company's shops. In addition, two Sheffield hand-cars and four standard track jacks were bought, and a 6 x 20-ft. scowboat was built for use where the fill crosses bays of Lake Champlain.

The working force consisted of one foreman at $2.85 per day, five men at $2.75 and a recorder at $50 per month. The foreman and his men were also allowed $1 each per day, and they lived in a maintenance-of-way boarding car, cooking their own meals. They were company bridge carpenters. The recorder was a rodman from the survey party, and his expenses were about $2.25 per day. The cost of boring outfits was as follows:

2 double A-frame drilling outfits	$299.22
4 standard track jacks	43.36
2 Sheffield hand-cars	63.00
1 boat	101.30
Total	$506.88

In a report by Mr. Mansfield, the company's valuation engineer, it is pointed out that the outfits can be used to great advantage by the maintenance-of-way department when the valuation department is through with them.

By the use of the outfits over an aggregate of about 12 miles, 1,870,883 cu. yd. of filling material and 45,603 cu. yd. of riprap were discovered. This work was done at a total cost of $1,570 exclusive of plant investment or at a cost of 31.82 ct. per lin. ft. inclusive, or 25.56 ct. exclusive, of the recorder. The total cost per yd. of all material disclosed was less than 0.1 ct, per cu. yd.

Wash Borings on the Ashokan Dam Site. A paper by J. S. Langthorn, in *Engineering and Contracting*, June 23, 1909, describes the methods used in making wash and diamond drill borings for the Ashokan dam site in the Catskill Mountains. The diamond drill work is described in my "Handbook of Rock Excavation," as are also the pressure tests of the bore holes to determine the seaminess of the rock.

The methods used to interpret results of wash boring on this work were of special interest. One man was able to take care of four boring rigs, and one test pit, and to take ground water observations on completed holes. He took samples on holes in progress, water observations on completed holes, assisted in locating holes and made monthly estimates on test pits. A one-horse conveyance was used to travel from one boring to another, when they were at some distance, and also to carry core boxes, sample bottles, marking boards, etc.

Dry and wash samples were placed in small bottles, corked and carefully labeled. These were placed in drawers which were systematically arranged and so subdivided that the samples from any hole could be readily found.

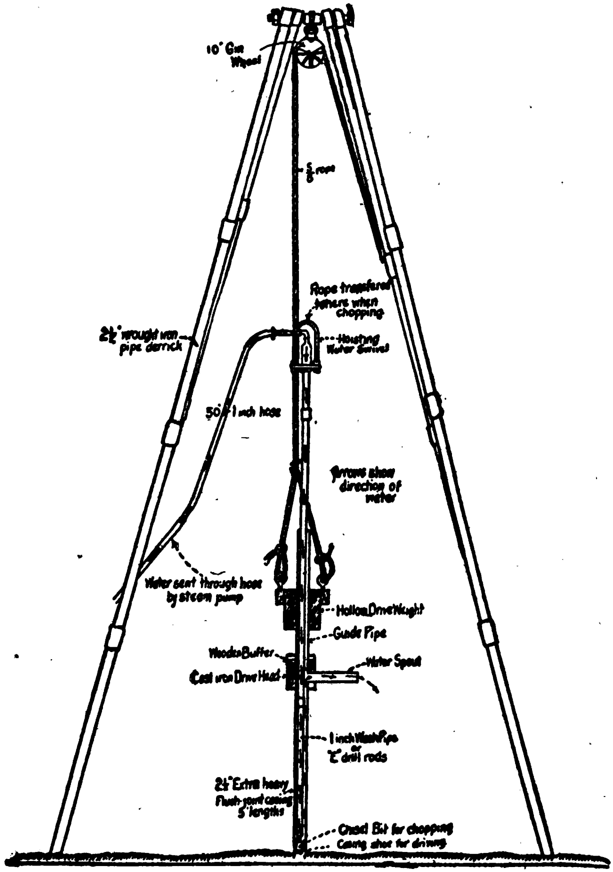


Fig. 11. Outfit for Making Wash Borings on Ashokan Dam Site.

Upon being removed from the core barrel of the boring machine all cores were stored in core-boxes. Each box contained

room for four rows of core in the bottom of the box together with three shelves for three rows each. A box would hold about 37 ft. of core, which generally represents about 40 ft. of actual drilling.

The core was labeled, boxed and stored in a small portable building shelved on all sides, where the core boxes were properly painted with number and depth of hole. Here they were readily available for future inspection. In addition to the core boxes, cabinets containing drawers were provided for filing the samples.

Instructions to Inspectors of Borings. A copy of the following instructions was given to each inspector for his guidance:

These borings and test-pits are being made to ascertain: The character of the overlying material; the elevation of bed-rock; the quality of this rock and incidentally all data that would aid in the selection of the best dam site.

In order to get an accurate determination of these conditions much depends upon the faithfulness and good judgment of the observer. His interpretation of the material must be based on the samples taken and careful observation of the mechanical operations of the machines and the wash which comes up through the casing. The following are some of the general rules which the inspector should be careful to note.

1. Observe very carefully the character of the material washed up and the color of the escaping water. Upon the proper interpretation of the above depends very much the value of the test hole; for, no matter how good or how accurate the samples may be, the true nature of the ground is best obtained by observing the mechanical operations involved. For instance, the wash may be clayey while the sample will contain no trace of clay; but the observer should record clay present as noted from the discoloration of the escaping water.

2. Take a sample for every 10 ft. driven and, if the material changes rapidly, a sample should be taken at every decided change. Should less than 10 ft. be made in a day, one sample will then be sufficient. There are two methods of taking samples of materials. A, the dry method, B, the wash method.

A, the *dry method,* is by far the more satisfactory when very accurate results are required. It is, however, an expensive and tedious method of procuring results. A 1¼-in. perforated wrought-iron pipe is driven into the material below the casing. The pipe has holes in it so that the water may be easily displaced when the sample of compact material enters the bottom of the pipe. For sand or material which would fall out of the sample pipe on being lifted, a "sand spoon" is used, a pipe with a closed pointed end, with a slit or opening about 1 ft. from the point.

This is driven into the material, and, on pulling it up, the sand enters the spoon and is so brought to the surface. In this way the material is obtained just as it exists.

B, the *wash method*, is as follows: In a tub or a half-barrel with a glass panel in one side, the wash, which comes up through the casing, is allowed to flow. If conditions are right and the tub becomes full, it is placed at one side and about a teaspoonful of hydrochloric acid mixed with water. The action of the hydrochloric acid is very decided. It takes about 30 min. to settle, while with no acid, it would take half a day. The settlement of the material may be seen through the glass panel. When settled, siphon off the clear water and the washed sample remains. Fill a sample bottle with the material, label with date, depth of hole and description of material.

Take dry samples, owing to their expense, only of material which may be regarded as porous, *i. e.*, sand and gravel, sand, or sand with a little clay; otherwise the wash sample, combined with the proper observations, will serve all general purposes. Never take a sample directly after a blast, nor when the wash pipe is too far ahead of the casing. The best time is when the wash pipe is about 3 in. ahead.

3. Make a concise record of the action of water in all boring operations. Should the water forced down the wash pipe fail to come to the surface again, it should be recorded as "losing water." This would signify that the material is water bearing or porous, or it may be a seam or cavity such as may exist in rock. Should the water stay at the top of the pipe it would show the impervious nature of the underlying material. The water may flow out of the top of the casing, indicating that a stream of water has been encountered with a greater head than that in the pipe.

4. It will not be sufficient to report a material as "clay and sand," for clay and sand in different proportions and under different conditions may vary from a very soft material to hardpan. They may be stratified or exist as separate pockets or closely intermingled, and all these conditions may be upset when water is present. A proper description should read as follows:

From 90 to 100 ft.—Hardpan, *i. e.*, clay, small stones and boulders in a very compact mass. Must use dynamite almost constantly in order to make any progress.

From 100 to 140 ft.—Clay and sand. Material very soft, the weight of rods being sufficient to penetrate material which stands up well and does not fill in when casing is removed.

5. The inspector must bear in mind the possibility of large

boulders existing, and should constantly be on the lookout for indications of them in the drilling.

NOTE: In this locality boulders greater than 20 ft. in any dimension were not met with, but some were found that were 10 or 12 ft. through. Consequently, when bedrock was reached, it was decided to drill 20 ft. to make certain it was not a boulder.

Conclusions.— The experience gained in the borings at the Ashokan Reservoir led to the following conclusions:

1. A washed sample without proper observations was of no value as a record, while greater weight given to the inspection of the boring operations would approach the actual conditions much nearer.

2. A dry sample was more satisfactory, but, without the inspector's observations, was not sufficient.

3. Invariably the proportion of clay given in boring records was too small.

4. The coarser materials, such as boulders, cobbles, etc., were not given enough weight.

5. Small stones would be chopped up by the bit and on coming up through the casing would be interpreted as sand.

6. If water was lost it was in a pervious material or water-bearing stratum with little or no clay present, or a seam in rock.

7. If material was recorded as "sand and gravel" with no loss of water, it was probably an incorrect record, for clay generally was present.

8. The percentage of core obtained, everything else being equal, varied directly with the hardness of the rock.

9. A larger percentage of core was possible with a bit of large diameter.

10. The conglomerates and harder sandstones yield nearly 95%, while the softer, loose and tilted shales yield less than 25% of core at best.

11. A good hard rock suitable for foundation or construction may be granular or nodular in texture and consequently give very little core and that very seamy. This core would be recorded as seamy and would give a false impression of actual characteristics.

12. The amount of core should be but a small factor in a general determination of the quality of the rock. The improper setting of a bit, excessive vibration of the rods, too strong a force of water, or the grinding away of the core, will reduce the amount obtained.

13. Vertical seams will reduce the amount of core. One case is worthy of mention: Ten feet had been drilled and the working

of the machine showed no unusual conditions. On pulling up the core barrel, it was found that only 1 ft. of core had been obtained. A weighted tape was dropped into the hole to see whether any core was left, but the hole was found clear and empty. By careful inspection of the core that was obtained, the presence of a vertical seam was discovered. The machine showed no indications of soft rock or horizontal seams in the running, the wash came up throughout the run with good blue-stone cuttings. It was concluded, therefore, that the bit had been in a vertical seam and was cutting good rock with its outside diamonds and consequently no core was made and a report to that effect was sent to the office.

14. It is possible from inspection to see whether detached pieces of core are broken mechanically or whether seams exist.

15. Boulders greater than 12 ft. in vertical dimensions were not encountered in the glacial till of this section.

Boring with Augers. A common wood auger, welded on to the end of lengths of gas pipes or other rods and turned by men with levers, may be sunk from 25 to 100 ft. in ordinary earth. When sand is the material to be penetrated, an outer casing of pipe may be driven with mauls or weights in order to prevent the sides of the hole from caving in. Hardpan, gravel and difficult materials cannot be penetrated by augers. For ordinary materials, however, this method will give fair results if the observations are made with care and intelligence. Some so-called earth augers are not true augers but are really spoons or pods which are twisted or driven down into the soil and then raised for removal of the spoil. Care should be taken not to drive the spoons or augers too deeply without raising them for cleaning. All devices of this character tend to show the earth penetrated as being more compact than it really is.

A Simple Boring Device. In commenting upon the failure to investigate the foundation of a high embankment in *Engineering and Contracting*, May 17, 1911, the writer described a very simple boring device. The instrument is a bar of hexagon or octagon steel, the end of which is swedged and enlarged at the butt and tapered to a point at the ends; the sides of the head are corrugated with a cutting edge. (Fig. 12.) On the opposite end the bar has a T handle riveted firmly to the shank, and this shank or rod may be 20 to 25 ft. long, often more. The method of operating is to raise this rod to a vertical position with the sharp bit on the ground, and then by churning the rod drive it into the earth until the bit reaches an obstacle. If continued churning does not remove or penetrate the obstacle in its path, several hard churns will dislodge particles from the obstruc-

tion, and by twisting the handle around several times the particles will lodge within the cutting edge of the bit, and may be brought to the surface, where they may be examined.

In open-cut mining work, it was customary to lay off a tract of land to be examined in squares of 10 ft., so that each square contained 100 sq. ft., staking the corners. At each stake soundings were taken to the ore bed. Two men were sufficient, and they were capable of sounding from 10 to 15 holes per hr.

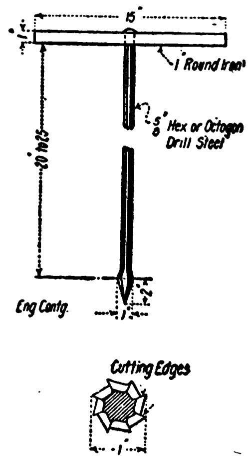


Fig. 12. Sketch of Device for Boring.

A Hand Auger for Prospecting. The hand auger shown in the accompanying illustrations, from *Engineering and Contracting*, Jan. 19, 1910, was developed by Baird Halberstadt, engineer and geologist, Pottsville, Pa., in the course of his work in prospecting some new coal fields in West Virginia.

The tool, Fig. 13, consists essentially of four parts — a heavy auger, a handle, a cutting bit and a number of sections of 1-in. gas pipe (one 8 ft., the others 3 ft. in length), threaded at both ends and fitted with ferrules. The auger is made of ¼-in. steel, 4 turns in 13 in., rounded and threaded to fit the ferrule, and to this are screwed the sections of pipe as the depth of the hole increases. It has been found well to have the first section made longer than the others, as the handle can be passed up and down as required without entirely uncoupling it, as becomes necessary when passing over a ferrule. The handle is made in two sections,

as shown in the drawing; the joining ends are held firmly by two bolts, and a circular hole drilled of a diameter slightly less than that of the pipe. With the bolts tightened up fully, the pipe will twist before the handle will slip around the pipe.

For holes exceeding 10 ft., when loose rock is encountered, a cutting bit replaces the auger until the obstruction is passed

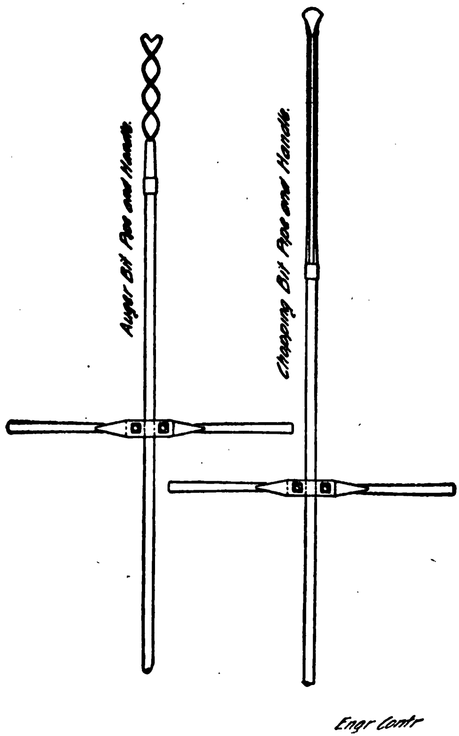


Fig. 13. Auger for Making Test Borings.

through. It has been found that greater speed can be made by using for holes where obstructions are met at a depth of less than 10 ft. and more than 4 ft. Ordinary jumpers are made of $1\frac{1}{8}$-in. octagon steel of good quality. The bits are of the round rather than triangular shape. Two of these are usually carried with the party, one 6 ft. and the other 10 ft. long. Fig.

14 fully explains the forms of each of the parts. Any good colliery blacksmith should be able to make one at a cost not to exceed $15.

The outfit consists of 2 auger bits (one for any emergency, although but two or three were broken in drilling the 65 miles outcrop), a cutting bit, 2 jumpers 6 and 10 ft., one-half dozen 18-in. bastard files for sharpening the blades of the auger, an

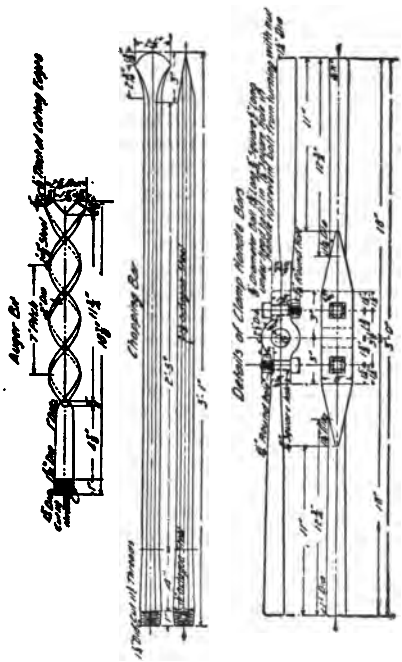


Fig. 14. Details of Bits for Test Boring Auger.

8-lb. striking hammer, an 18-in. Stilson pipe wrench, a monkey wrench for loosening the bolts in handle, a galvanized iron bucket and tin cut, a mattock and short handle shovel, an oil cadger filled with lubricating oil for use on ferrules and pipes, and a short handle cutting axe.

The entire outfit can be carried readily by a party of three men almost anywhere. In fact where the holes are not far apart two men by making an extra trip can transport them. It

has been found advantageous to use three rather than two men to a crew, as three can work to far better advantage, and the difference in cost is more than made up by the increased amount of work accomplished.

If the hole is on the slope of a hill, a space of say 2½ to 3 ft. square should be leveled off with a mattock and spade. This gives the men firm foothold. The auger (attached to an 8-ft. section of pipe to which the handle is securely fastened) is put down and the handle turned until the auger has cut through 7 or 8 in. of "wash"; it is then removed and a cup or two of water is poured into the hole and drilling is resumed. The purpose of the water, if the ground is very dry, is to dampen the soil, but not to make it too wet. The material cut through will then cling to the auger, filling the grooves, and the whole can be quickly removed when the auger is withdrawn. On each drawing up of the auger a small quantity of water is introduced.

The advantage of the auger over the churn drill is here exhibited, for with the former neither a scraper, swab stick nor sand pump is required, while with the latter the whole mass must be made pasty, so that it can be drawn up with swab stick or in a sand pump. Another advantage the auger has is that the sides of the hole become packed hard and no difficulty is experienced from caving in. The holes drilled with it, if covered, remain open for many months. The sand pump was used only in extremely wet holes and generally it was only necessary to use it when holes were drilled near water level. Throughout this entire work the sand pump was resorted to in but a few instances.

Hook Connections for Auger Rods. These were used in making subsidence tests on the Chicago, St. Paul, Minneapolis and Omaha Railway, as described by M. M. Wilcox in *Engineering News-Record,* May 3, 1917.

As some of the holes bored were more than 50 ft. deep, to unscrew joints every time the auger was pulled up for cleaning would have been slow work. With the hook connections the rods were disconnected as fast as they were lifted from the hole, and still there was no chance for them to become disconnected while in a vertical position.

The tools used for the tests were a carpenter's 2-in. auger, a 2-in. pod auger, a short drill, two bars, 5 and 8 ft. long respectively, both of 1-in. drill steel, a supply of 2-in. single-strength pipe and couplings for casing the hole in soil that caved, a Channon pipe lifter with a Little Giant pipe holder, wooden mauls for driving the casing, a shovel and post-hole digger for use in going through the ballast, a short piece of

heavy log chain with hook and eye, two pipe wrenches and a supply of extension rods. The augers and drill each had a shank 4 ft. long with an eye at the upper end so that an extension rod could be hooked on as the hole was lowered. These extension rods were of ½-in. round steel, 8 ft. long, with an eye at one end and a hook at the other. There was one rod 4 ft. long to use in connection with the longer ones, so that there was never more than 4 ft. out of the ground at a time.

The method followed in making these tests was to put a hole through the ballast with the shovel and post-hole digger, than set in a length of the 2-in. casing and use the auger the rest of the way, lowering the casing as the hole progressed. If the fill was of clay or any material that would stand without caving, it was often possible to complete the hole with only the one piece of pipe, as that would keep the ballast out of the hole. Where the fill was dry sand, or if there was water

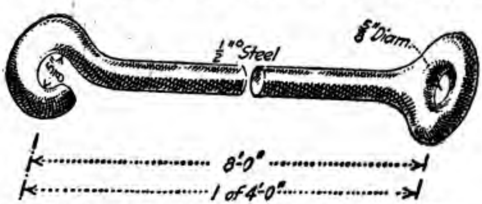


Fig. 15. Extension Bar for Boring Auger.

on the sides of the fill, it was necessary to keep the casing close to the bottom of the hole; and in some holes better progress was made with the casing driven lower than the hole, the material being bored out inside of the casing.

In a number of holes small gravel stones were found which caused a great deal of trouble, until a 3-ft. piece of 1½-in. pipe (the largest that would go inside the 2-in. casing) was fitted with an eye at one end so that the extension rods could be hooked in. This pipe was churned up and down in the hole until the gravel had become wedged in the pipe. In this way any stone that would go in that pipe could be removed. At times the stones were too large to be removed in that way, and it was necessary to drive the casing down until the stone was wedged in it. The casing was then pulled and cleaned. In some holes it was possible to replace the casing without losing any of the hole, but at other times it was found that from 5 to 50% of the hole had filled and would have to be bored out again.

Auger Borings on Sewer Construction. In *Engineering and*

Contracting, March 23, 1910, Roger DeL. French describes test borings for sewer construction at Louisville, Ky., where wash borings were taken on the line of proposed sewers by a superintendent and (usually) four men. Oftentimes a bore hole could be put down to its full depth with a post-hole auger, but small holes required to be cased with 4-in. pipe and sunk with a sand pump. The cost of these holes ran from 2 ct. to as high as 20 ct. per ft., according to location, material penetrated and number of holes in one group. Four men and a superintendent could put down an average of 180 ft. per day of 8 hr. in the clay, sand and gravel underlying Louisville.

Cost of Test Borings for the Winnipeg Shoal Lake Aqueduct. Much test boring was done during the winter of 1913–14 in examining the proposed location of the aqueduct from Shoal Lake to Winnipeg. A description of this work and cost data are

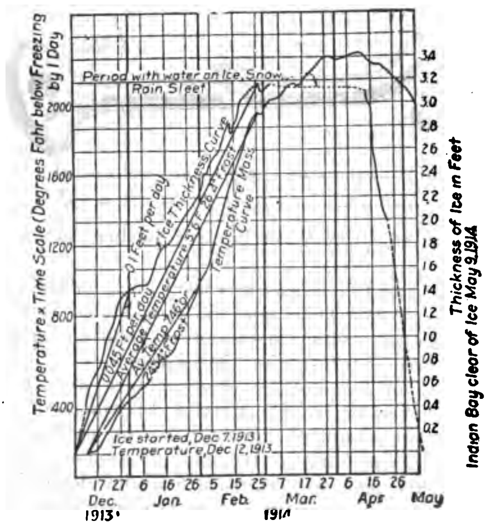


Fig. 16. Ice Thickness and Temperature Curves for Indian Bay, Shoal Lake, Greater Winnipeg Water District, 1913–14.

given by Douglas L. McLean in *Engineering and Contracting*, April 7, 1915.

This work was carried on under the severe climatic conditions of a Manitoba winter. Maximum ice conditions on Shoal Lake from December, 1913, to June, 1914, are shown graphically

on Fig. 16. This chart shows the growth of the ice from day to day on an ice space kept clear of all snow. Corresponding to the curve of ice thickness is a temperature curve to show the amount of cold which produced this ice. In order to measure this in degrees below freezing over a stated period, the ordinates for the curve were taken as "degrees Fahrenheit below freezing times one day." The maximum depth of ice on snow covered portions of the lake was 2.3 ft. thick as compared to 3.2 ft. on clear space. On the peat bogs the depth of frost averaged about 2 ft. The maximum depth of frost encountered was 3.7 ft. in sandy soil while the minimum in sheltered snow covered places was 1.5 ft.

The located line for the section of the aqueduct on which Party No. 3 made borings ran for the most part through a clay country covered with peat bogs. For the seven miles from Snake Lake to the Boggy River the peat bog averaged about 8 ft. in depth.

Cost data relating to a portion of the test boring work are given under the following headings: (1) Salaries and board allowance. (2) Empire drill costs. (3) Hand auger costs. (4) Wash boring costs.

Salaries and Board Allowance. The following were the standard rates paid by the Greater Winnipeg Water District:

Instrumentman, per month	$100*
Leveler, per month	90
Topographer, per month	75 to $80
Field draughtsman, per month	60 to 70
Rodman, per month	40 to 45
Head chainman, per month	40 to 45
Rear chainman, per month	35
Head picketman, per month	40 to 45
Cook, per month	60 to 75
Cookee, per month	35
Leader, per day	1.75
Laborer, per day	1.50

* All grades were boarded free while in the field. An additional allowance of 15 ct. per day per laborer while on boring was given to make up for extra wear and tear on mitts and clothing.

For the boring costs given in this article a board allowance of $1.05 per working day has been charged.

Empire Drill Costs. Total and average costs for 645 ft. of boring using the small auger drill spoon with necessary drill rods, wrenches and handles of a Junior Empire Drill Set, are given in Table I. The Junior Empire Drill Set ordered by the district cost $260 delivered at Winnipeg. It was supplied by the New York Engineering Co., whose catalog gives a complete description of its various parts. The test holes put down were

at 2,000-ft. intervals, averaged 22.2 ft. in depth and cost 32.4 ct. per ft. run, including the peat in the depth.

In opening up the holes through the frozen material axes were used on all hand auger work, as the axe was found more efficient than a chisel, crowbar or pick.

TABLE I. HAND AUGER TEST BORING COST DATA, WINNIPEG AQUEDUCT

(Small "Empire Drill" earth auger used without casing as hand auger)

	Totals
Number of holes	29.0
Frost depth in feet, 1	55,9
Peat depth in feet, 2	234.1
Sand and gravel depth in feet, 3	0 9
Clay depth in feet, 4	409.7
Total depth in feet of 1, 3, 4	465.5
Total depth in feet of 2, 3, 4	644.7
No. of men per day or man-days	65.8
Cost per day	$208.66
Work done from Feb. 4–18 —	**Feet**
Average depth frost per hole	1.93
(This is frozen peat and water.)	
Average depth peat per hole	8.07
Average depth sand and gravel per hole	.03
Average depth clay per hole	14.10
Average total depth	22.20
Average cost per foot run, 1, 3, 4, ct.	44.8
Average cost per foot run, 2, 3, 4, ct.	32.4
Average cost per man-day	$3,175
Average man-days per hole	2.27
Average man-days per foot run, 1, 3, 4	0.141
Average man-days per foot run, 2, 3, 4	0.102
4-men gang —	
Average cost per day	$12.70
Average bored, 1, 3, 4, feet per day	28.4
Average bored, 2, 3, 4, feet per day	39.2

Note.— Cost of auger, axes, etc., not included in table.
These holes were about 2,000 ft. apart and considerable time was required transporting outfit and traveling to camp.

Hand Auger Costs. Table II gives the cost of some 6,200 ft. of boring for which was used the hand augers shown in Figs. 17 and 18. These hand augers give practically the same efficiencies for depths of 15 to 20 ft., but for depths under 15 ft. the pipe auger is the faster. The rod auger, Fig. 17, consisting of 1 auger piece, 1 handle, 5 extension rods with 12 extra bolts ⅜-in x 1¼-in., cost $10.70. To this should be added cost of a couple of spanners and a handle for lifting.

The pipe auger, Fig. 18, consisting of 1 auger piece, 5 rods with couplings and bolts, 1 handle, 1 extra set of bolts and 2 spanners, together with 2 only ⅜-in. steel chains 4 ft. long, with one grab and one slide hook attached to each, cost $15.

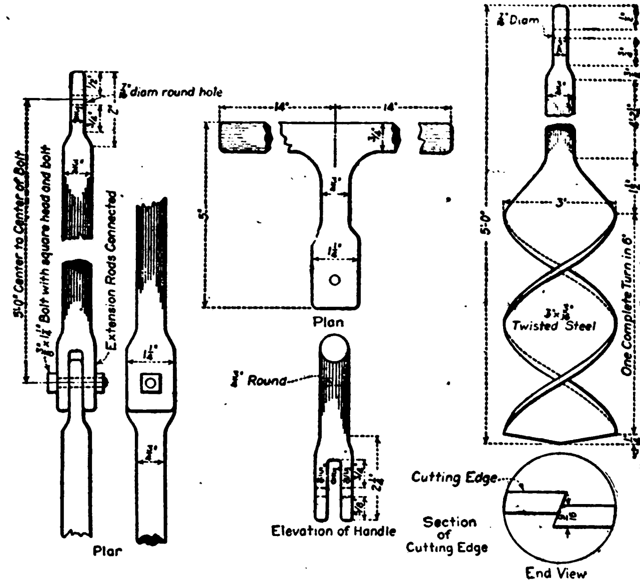


Fig. 17. Hand Operated Rod Auger Used on Wippipeg Shoal Lake Aqueduct.

TABLE II. HAND AUGER TEST BORING COST DATA, WINNIPEG AQUEDUCT

	Totals to April 22
Number of holes	370.0
Frost depth in feet, 1	759.6
Peat depth in feet, 2	2,490.9
Sand and gravel depth in feet, 3	59.3
Clay depth in feet, 4	3,352.3
Total depth in feet, 1, 3, 4	4,171.2
Total depth in feet, 2, 3, 4	5,902.5
No. of men per day, man-days	236.9
Cost per day	$662.70
Summary of results to April 22 —	
Average depth frost per hole, feet	2.05
Average depth of peat per hole, feet	6.73
Average depth of sand and gravel per hole, feet	0.16
Average depth of clay per hole, feet	9.06
Average total depth, feet	15.95
Average cost per foot run of 1, 3, 4, ct.	15.9
Average cost per foot run of 2, 3, 4, ct.	11.2
Average cost per man-day	$2.80
Average man-days per hole	0.64

Average man-days per foot run, 1, 3, 4	0.057
Average man-days per foot run, 2, 3, 4	0.040
3-man gang —	
Average cost per day	$8.40
Average bored, 1, 3, 4, feet per day	52.8
Average bored, 2, 3, 4, feet per day	75.0
Cost of equipment —	
3 rod augers at $10.70	$32.10
6 spanners at 20 ct.	1.20
3 monkey wrenches at 70 ct.	2.10
1 pipe auger at $15	15.00
4 10-qt. galv. pails at 21 ct.	.84
1 doz. 3½-lb. axes at $1	12.00
Total	$63.24

This equipment cost is not included in table.

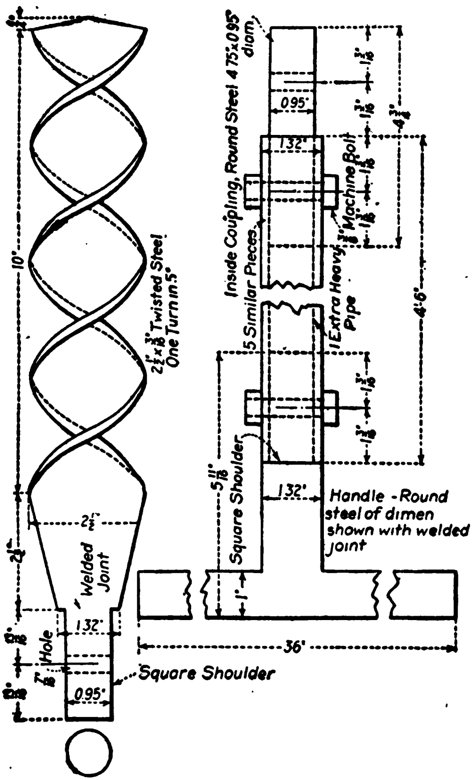


Fig. 18. Hand Operated Pipe Auger.

Boring with Hollow Pipe. In order to sample the material along the route of the proposed Boston subway according to *Engineering News*, Mar. 29, 1894, a pipe was driven down and then pulled up and the soil retained in the interior was removed. The depths reached averaged 25 ft.; a maximum depth of 38 ft. was obtained. A small derrick was used for pulling out the pipe and also for lifting the weight used to drive it. The earth which was forced into the pipe during the driving was in turn forced out by water, and a small tube was inserted into the pipe for the purpose of taking out samples.

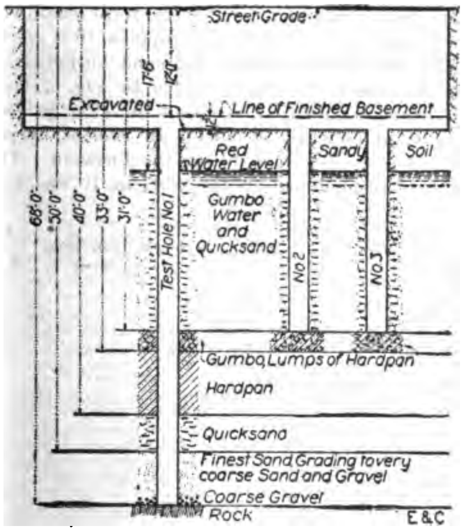


Fig. 19. Depth of Test Holes and Character of Sub-Soil.

Cost of Auger Holes in Oklahoma. Mr. F. O. Kirby, in *Engineering and Contracting*, Jan. 14, 1914, gives the method and cost of determining the soil conditions beneath a proposed five-story office building at Chickasha, Okla.

At one time there was a slough where this building stands, and as the town grew and the street was built up, the ground was filled in. In general, the soil on top of the ground to a depth of about 10 ft. was red sandy clay, with strata of gumbo and hardpan every few feet. Below a depth of 10 ft. the sand in the soil increased. The high-water mark during the wet

season was about 6 ft. below the street level, and the low point, as shown in Fig. 19, was about 17.5 ft.

The same strata were found in each of the three test holes. The first test hole was taken in the center of the basement, and the other two were taken at each side of it.

Holes Nos. 2 and 3 were made by a post auger, using pipe to lengthen the handle. No. 1 was started by driving a galvanized iron pipe in sections by leverage. At a depth of 25 ft. this pipe closed up so that it was impossible to get a 3-in. auger through it, nor could a sand bucket be used to clean out the pipe. A driver was then rigged up by using a set of leads with a railroad tie for a hammer. Laborers were employed to lift and drop the hammer, to drive a 4-in. pipe in 10-ft. sections, and to take out the soil with an auger and sand bucket.

The cost of the three test holes shown in Fig. 2 (totaling 91 ft.) is given below. This cost is based on 1912 prices for materials, the local union scale of 45 ct. an hr. for carpenters, 20 to 25 ct. for laborers, and 62.5 ct. for the foreman. The lumber in the derrick is not included in the cost, as it was used in the building.

	Cost
Driving test holes and removing wrought iron pipe, labor only	$ 34.45
Carpenters, building derrick	7.20
Carpenter, rigging	3.60
Post auger	2.00
15 ft. of 1-in. black pipe	1.05
15 ft. of 1-in. No. 22 well casing	2.70
1 sand bucket	4.75
12 ft. of 1-in. black pipe	0.78
27 ft. of 9-in. galvanized iron casing	6 75
2½-in. sand bucket	3.75
62 ft. of 3½-in. black pipe	28.52
2 couplings	0.80
2 caps	0.90
1 B. coupling	0.40
4 cuts and threading	1.60
15½-ft. of ¾-in. black pipe	0.78
2¾-in. couplings	0.15
Cutting and threading	0.25
Ring in pipe	0.15
4 guides for derrick	1.00
2 braces	0.50
Clamp to pull pipe	2.00
24 ft. of 9-in. casing	6.00
Total cost of 3 test holes	$110.03

Auger Boring with an Empire Drill. (*Engineering and Contracting*, Jan. 29, 1908.) The drilling is done with one of several tools, adapted to the particular kind of material being drilled — attached to the drilling rod. The tool and rod are operated inside the casing by the men on the platform, who raise and drop them like a "churn" drill. The men on the

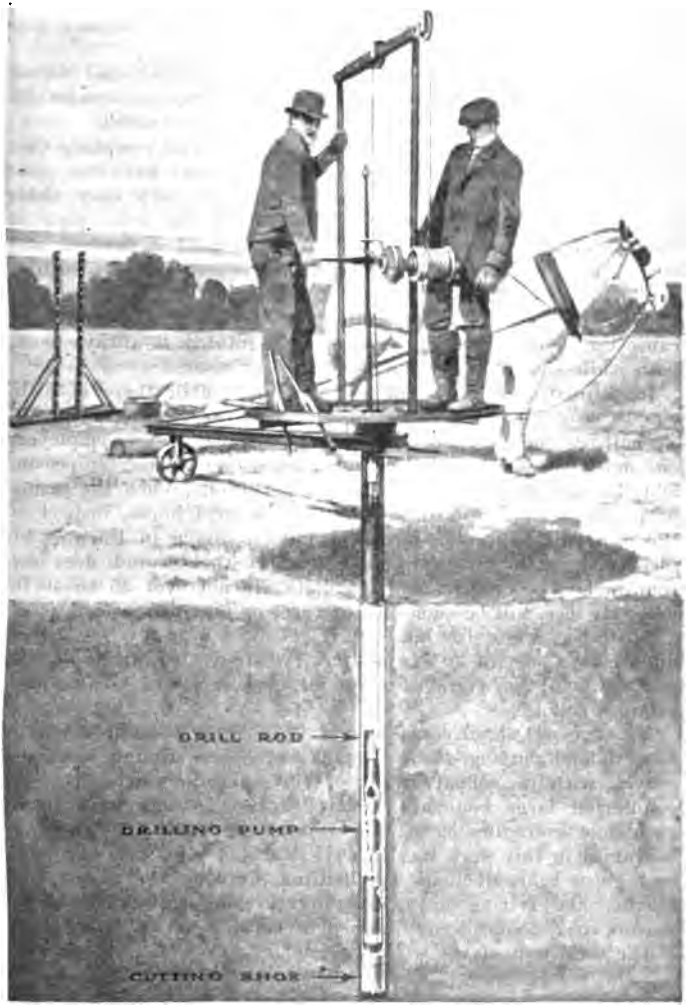


Fig. 20. Sectional View of Empire Drill, Made by the New York Engineering Co., 2 Rector St., N. Y.

ground rotate the casing, which has a sharp cutting shoe on the lower end. The casing, with its burden of platform and men, thus keeps cutting and sinking into the ground several inches ahead of the tool. A horse may be substituted for the men who rotate the casing.

The material which enters the casing is drilled and forced into a sand pump at the same time. The pump is occasionally lifted out of the casing, emptied and the contents noted.

Four-in. pipe is generally used, with a special coupling that makes a flush joint; that is, all of the couplings have the same outside diameter as the pipe, which makes it very easy either to sink or remove this casing. Instead of the 4-in. pipe or casing, 3-in. or even 2½-in. casing can be used if desired, and it will make more rapid work, but of course would give a smaller core.

After the hole is finished, the pipe is easily withdrawn because the casing, having been constantly rotated, is always loose, both while sinking and removing.

In estimating the cost of operating this drill there is little else to be calculated besides the labor, as the repairs constitute a small part of the operating expense. Of the laborers employed, one must be a foreman or driller, another an ordinary pipeman, and the balance of the crew common laborers. When the casing or piping with its platform is rotated with a horse, instead of the men on the ground, it effects quite a saving in the cost by dispensing with three or four men. If the ground does not contain heavy boulders, and the holes are not over 35 to 40 ft. deep, six men will be sufficient, or three or four men and a horse.

With the 4-in. size hole 50 ft. of hole per day have been drilled at a cost of 30 ct. per ft. Twenty-five to 30 ft. of hole per day will be averaged through hard cemented gravel containing boulders.

Mr. Thos. G. Ryan used one of these Empire hand drills on Long Island putting down a number of holes through sand and gravel, with occasional strata of clay, and in some cases encountering large boulders. About 40 test borings were made, each hole averaging 59 ft., the total being 2,454 ft. The time consumed in this work was 73 days, working 9 hr. per day. The cost given below includes the drilling, drawing the casing, and moving and setting up drill, thus covering a number of removals over a considerable period of time.

The total cost of the work was:

1 foreman 73 days at $4	$292.00
1 pipeman 73 days at $3	219.00

3 laborers 73 days at $1.50 each	$328.50
1 horse 73 days at $1	73.00
Depreciation, interest, renewals and incidentals	81.76
Total cost	$994.26

An Empire drill was used under the direction of Mr. Clarence R. Snow, during the autumn of 1908, in Colombia, South America. An account of this work appears in *Engineering and Contracting,* June 6, 1909.

The work was done with native peons or Indians, who had never seen machinery of any kind. The country in which the holes were being sunk was covered with forest, the bush and undergrowth in many places being very heavy. To move the drill from hole to hole a narrow path was cut through the undergrowth 6 or 7 ft. high. A small flat bottom boat was used to carry the drill across the river, there being consumed about half an hour to do this. As there are no roads in Colombia it would be almost impossible to work a steam drill, owing to the difficulty of moving it from place to place.

Four men were used to turn the casing, and four men did the drilling, an additional man being used for cutting trails. The entire crew was used to draw the casing and move the drill from hole to hole. The following is a record of seven days' work:

First day,— Carried outfit across river in boat and began hole No. 1. Made 14 ft. in top soil and 11 ft. in gravel by 5 P. M.

Second day,— Finished hole No. 1, 2.5 ft. more to bed rock, total, 27.5 ft. Pulled casing and began hole No. 2, 100 ft. distant before noon, and sunk the hole 17 ft. deep to bed rock before 4 P. M. Pulled casing and moved to hole No. 3, drilling 9 ft. in overburden.

Third day,— Finished hole No. 3, 24 ft. deep. Pulled casing and started hole No. 4 by 2 P. M. Passed through 12 ft. of overburden and 10 ft. of sand and gravel by 5 P. M.

Fourth day,— Finished hole No. 4, which was 28 ft. deep to bed rock. Pulled casing, cut trail and moved to hole No. 5, 300 ft. northeast of hole No. 4, and started new hole by noon. After drilling 17 ft. through overburden an old buried tree was struck, but the drill went through it easily. By 5 P. M. 22 ft. were made in this hole.

Fifth day,— Finished hole No. 5, 28 ft., and after pulling casing began hole No. 6. Got down 14 ft. in overburden and 9 ft. in gravel by 5 P. M.

Sixth day,— Finished hole No. 6, going down 9 ft. more to bed rock. Moved outfit across the river and about a mile up the

river, and at 2:45 started hole No. 7. Made 6 ft. in overburden and 9 ft. in gravel by 5 P. M.

Seventh day,—Finished hole No. 7, 29 ft., to bed rock, and moved 50 ft. north and sunk hole No. 8, 22 ft., to rock. Started hole No. 9, 50 ft. north, and made 6 ft. in top soil by 5 P. M.

Thus in seven days of drilling 213 ft. were drilled, an average of 30.5 ft. per day. It will be noticed that as the men became accustomed to the work, they improved a little each day.

With the Empire drill an auger drill spoon is used that will cut through hard soils, roots and sunken logs and easily penetrates gravel. It picks up any material and brings it as a core to the surface with a minimum amount of disturbance of the material as it actually lies in the ground. Water, as a rule, is not used to assist in drilling, so the auger will pick up the finest particles of gold. If it is desired to use water in drilling it can be done. The casing is pulled by levers with a very simple device.

With wages at $1 per day for the men the expenses were about $10 per day, allowing $1 for incidentals, the cost per ft. was about 33 ct. At American wages the cost would have been about 47 ct. per ft.

Post Hole Diggers are not true augers, but consist of a scoop or screw which fills itself as forced into the earth; when filled it must be lifted out of the hole and dumped. As this must be repeated for every few inches of hole the process is too slow for use on any but shallow holes.

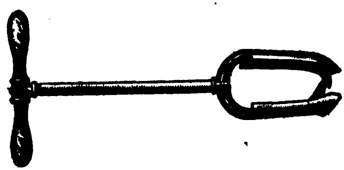


Fig. 21. Post Hole Auger.

A useful type of post hole auger is shown in Fig. 21, which is taken from *Engineering and Contracting*, Oct. 30, 1907.

The handle on the small sizes is 4 ft. long, while a 6-ft. handle is used on the larger sizes. For ordinary purposes these lengths are sufficient, but for boring test holes the handle is readily lengthened by attaching additional pipe of the same size as the handle.

With a 10-in. auger, holes 35 ft. deep have been bored, while with a 4-in. auger a depth of 75 ft. has been obtained. Where a

large number of shallow holes, from which specimens are to be taken are needed, this auger should give excellent results.

In the issue of Aug. 28, 1907, page 133, the cost of digging post holes for a fence with an auger is given. With wages at $1.50 per 10 hrs., 84 holes being dug with a 6-in. auger, the cost per hole was 1.8 ct., or .7 ct. per lin. ft., which gives a cost of 98 ct. per cu. yd.

The style of auger shown in the cut is made of two steel blades, each blade with two cutting edges. The blades interlock at the bottom in the notches made for that purpose, thus holding the dirt, which is released by rapping the flat side of the blade on the ground. The auger is made in ten sizes from 3 in. to 14 in.

Boring with Post Hole Diggers on Long Island. In tests for the adlitional water supply of the city of New York, as reported in 1903, some 22 test pits were dug near the South shore of Long Island with 4½-in. and 6-in. post augers, at a total cost of about $14.50, or 66 ct. per hole. The total number of feet was 102 and the cost per ft. therefore amounted to 14 ct.

Cost of Post Hole Digger Boring. Emile Low in *Engineering News*, March 21, 1907, describes the work of making earth auger borings on the New York State Barge Canal. The tools used consisted of a light steel cylindrical pod (6 in. in diameter and having a length, including the serrated bottom edge, of 5 in.) composed of 5 saw-shaped teeth 2 in. long. These teeth were bent inward more or less according to the character of material penetrated. The rods were made so that they could be screwed into a standard section of gas pipe 8 ft. long. A suitable handle was provided to grasp the pipe with which the earth auger was turned. The work of boring the holes 6 in. in diameter was accomplished by turning the auger until the pod was full of earth, then lifting it out and emptying it. In suitable soils holes 16 ft. long were readily bored. In the work described 450 holes were driven an average depth of 13.26 ft. The cost of these borings was 18.3 ct. per ft.

Material, muck, sand, clay and gravel.

Force employed per day: three laborers at $2.00; at times 1 horse and buggy for transportation of men and tools, $2.00. Daily progress, 3 holes or 40 ft.

See my "Handbook of Cost Data" for further information.

Cable Drills. In my "Handbook of Rock Excavation," pp. 252–295, methods and costs of using cable drills are given. This method of drilling consists in alternately raising a string of tools which terminate in a chisel cutting edge and letting them fall. The chopping motion imparted to the cutting tools enables them

to penetrate through coarse gravel and boulders that could not be passed by the wash boring method without blasting.

Diamond Drills are used for prospecting rock rather than earth. Their chief interest from a standpoint of earth exploration is their use to distinguish large boulders from ledge rock.

Cost of Test Wells for a Bridge Foundation. P. J. Robinson in *Engineering and Contracting*, Jan. 5, 1910, gives the following:

Test wells were bored to determine the nature of the foundations for the piers of a bridge over the American River, California. Stagings were erected from the side of an old bridge and equipment, which consisted of a gasoline hoist and drill machine, was rented from a local well borer, who also supervised the work. Three crews prosecuted the work at the start, ending with one, with wages as follows:

Engineman	$4.75
Foreman	4.00
Sub-foreman	3.75
Sub-foreman	3.50
Sub-foreman	3.25
Laborers	3.00
Laborers	2.75
Laborers	2.50
Laborers	2.25

A suction sand pump, a design of the local shops, was used through the gravel and cobbles and an earth auger in the clay. The wells were encased with sheet iron and when possible the pipe was pulled and used again. The prices charged for this material are shown in the cost statement. The wide range in cost of the different sizes is due to the fact that the 14-in. and 12-in. pipe were new, while the 10-in. and 8-in. were second hand.

The work was twice interrupted by high water, necessitating the dismantling of the equipment, and thereby adding quite materially to the cost.

The cost of this work was as follows:

Labor —		
Loading and unloading material, 63½ days		$ 197.00
Hauling material, 2 days		6.50
Boring well No. 1, 107 days		324.25
Boring well No. 2, 52 days		165.75
Boring well No. 3, 131½ days		417.62
Boring well No. 4, 51½ days		171.50
Boring well No. 6, 117½ days		360.00
Erecting staging, 68½ days		236.81
Repairing derrick, 2 days		7.00
Making boxes of test well soils, 4 days		15.00
Rental of well boring apparatus		118.00
		$2,019.43
Material —		
Lumber, 9,073 ft. B.M. at $13.83 per M.	$125.47	
Sheet iron casing, 14-in., new, 52 lin. ft. at $2.75	143.00	

Sheet iron casing, 12-in., new, 172 lin. ft. at $2.25	$387.00	
Sheet iron casing, 10-in., second-hand, 49 lin. ft., at $0.60	29.40	
Sheet iron casing, 8-in., second-hand, 36 lin. ft. at $0.51	18.36	
Store department expense	40.55	
2% of labor for use of tools	40.40	784.18
Total		$2,803.61

No. lin. ft. bored, 534.5 — cost per ft., $5.25.

Of the five wells bored, No. 1 and No. 6 were on the bank and Nos. 2, 3 and 4 were located in the channel of the stream. It is noted that well No. 3 was the most expensive to bore, due to the nature of the substance penetrated.

Cost of Test Pitting. The following are costs given in the *Engineering and Mining Journal* of test pitting in hard clay and hardpan with many large boulders, where the ground dulls the picks rapidly. Foreman's wages were $3; laborers, $2. Two-inch hardwood plank was used for cribbing when necessary. No superintendence or office expense charged.

Pit	Depth, feet	Hours, labor	Cost	Per foot
1	17	80	$18.00	$1.06
2	24	140	29.00	1.21
3	7	15	3.50	0.50
4	22	75	16.50	0.75
5	23	100	24.00	1.04
6	26	240	48.00	1.84
7	41	270	56.00	1.366
8	46	335	72.50	1.58
9	38	255	64.00	1.70
10	33	240	54.00	1.67
11	10	60	12.00	1.20
12	9	100	22.00	2.44
13	9	20	4.00	0.44
14	17	60	12.00	0.70
15	12	55	12.50	1.00
Filling pits Nos. 1, 2, 3, 4			6.00	....
Filling pits Nos. 5, 6, 7, 8, 9, 10			35.00	....
Filling pits Nos. 11, 12, 13, 14			7.00	....

The contract price for sinking a test pit in sandy soil and doing all necessary cribbing, all supplies to be furnished and tools sharpened free of charge, to 20 ft. in depth is $1 per ft.; from 20 to 30 ft., $1.25 per ft.

Test Trenches. Trenches used in prospecting a mining property are described in *Engineering and Contracting*, June 21, 1911. A trench 60 ft. long, 6 ft. wide and 7 ft. deep was excavated by 6 men with picks and shovels in 3.2 days. A staging was then put in, three additional men were hired to re-handle the earth, and the trench was deepened 8 ft. to rock.

The cost of excavating 146.7 cu. yd. of earth from the trench was as follows:

Six men 3 days at $3	$ 54.00
Nine men 2 days at $3	54.00

Six round-point long-handled shovels	$ 9.75
Three square-point D-handled shovels	4.00
Six 5-lb. drift picks	8.00
Six 36-in. drift pick handles	1.90
172 ft. lumber for staging	3.10
	$134.75

Cost per cu. yd., $0.918.

Bibliography. "Hand Book of Rock Excavation," H. P. Gillette. "Cost Data," H. P. Gillette.

"Boring Test Holes with an Auger," Charles Catlett, *Trans. Am. Inst. M. E.*, Vol. 27, 1897.

"Methods and Costs of Wash Borings, Great Lakes and Atlantic Ship Canal Survey, 1897–1900," *Eng. and Con.*, Mar. 27, 1907. "Comparison of Cost with Two Light Wash Boring Rigs," A. W. Saunders, *Eng. and Con.*, Dec. 9, 1908. "Cost of Making Test Borings with Wood Augers," A. C. D. Blanchard, *Eng. and Con.*, Aug. 11, 1909.

CHAPTER IV

CLEARING AND GRUBBING

The removal of trees, brush, and stumps, from areas to be excavated or on which embankments are to be built is a subject of importance too little considered by excavating engineers. Often where cuts are shallow it costs more than the excavation. In spite of this it is not unusual to see costs of excavation figured to hundredths of a cent per cu. yd. and the cost of clearing and grubbing merely guessed at, or at the best, so stated as to be valueless. The reader is referred to "Clearing and Grubbing," a 250-page book by the author of this work, from the first chapter of which the following discussion is largely taken.

Factors in Clearing and Grubbing Cost. *Clearing* consists in cutting down and removing or burning trees and brush, except the stumps. *Grubbing*, or stumping, consists in excavating and removing stumps. The unit of measure is usually the acre, but occasionally the square rod (160 per acre), and at other times the "great square" (100 x 100 ft.), is the unit of measure for grubbing. In railroad work, a "station" of 100 ft. in length and a width equal to that of the right of way is usually the unit of clearing.

In clearing trees, the following are important elements affecting the cost per acre:

1. Number of trees per acre.
2. Average diameter.
3. Average height.
4. Kind of tree.
5. Density of wood.
6. Whether the logs and limbs are cut up and hauled off, or are chopped into cordwood, or are burned.
7. Weather conditions.
8. Efficiency of workmen and wage rate.
9. Size of job.

Unfortunately no published record of the cost of clearing gives all these factors, but many give a sufficient number of the factors to guide the reader sufficiently well.

In grubbing stumps, the following are important elements affecting the cost per acre:

1. Number of stumps per acre.
2. Average diameter at cut-off.
3. Kind of tree.
4. Green or dead.

5. Kind of earth and degree of wetness.
6. Pulled or blasted.
7. Type of roots.
8. Burned or hauled away.
9. Weather.
10. Ground frozen or not.
11. Efficiency of men and wage rate.
12. Size of job.

In addition to the above factors the cost of excess excavation required to fill stump holes under embankments must be taken into consideration.

Types of Roots. Tap roots are the most difficult to pull or blast. The long-leaf yellow pine of the South is typical of this class. Hickory, white oak and black gum also have tap roots.

Semi tap roots are the most common variety. The class includes white pine, poplar, chestnut, ash, walnut, persimmon, sassafras, various varieties of oak and most fruit trees.

Lateral root trees are less numerous than other kinds. This class includes elm, soft maple, locust, hemlock, dogwood and elder. These three types of roots merge into each other. Soil conditions also affect the form of root growth so that an absolute classification is not possible.

Some stumps are durable and others will rot very fast. A stump that does not sprout is not getting any worse as time passes, but one that does sprout is likely to be harder to take out each succeeding season.

For accurate estimates of the cost of either clearing or grubbing, the number of trees per acre should be known approximately. If the trees are classified according to size, more accurate estimating becomes possible. Much yet remains to be printed relative to clearing and grubbing costs per tree of different kinds before an entirely inexperienced man can make a very close estimate of costs per acre.

In chopping or sawing trees the account of work varies about as the square of the diameter. Therefore the work done in cutting down a 48-in. tree is 16 times as great as that on a 12-in. tree of the same kind. If done entirely by hand, the total labor of clearing away a 48-in. tree will be more than 16 times that required by a 12-in. tree, for the trunk will be longer, requiring to be cut into more sections before it can be moved. Also trees of such large diameter are difficult to handle with a cross-cut saw so that even the difficulty of falling increases at a greater rate than the square of the diameter.

Suggestions as to Estimating Costs of Clearing and Grubbing.

In *Engineering and Contracting*, Sept. 6, 1911, the author published the following:

Any one who has not seen the trees of western Washington and Oregon may find it difficult to believe that clearing and grubbing has often cost more than $500 an acre in that section of the country. Yet on a recently built electric railway along Puget Sound the cutting of trees and yarding the logs on the right of way ready for loading cost $280 per acre, and the subsequent pulling of stumps, stacking and burning of all refuse on the right of way cost $300 per acre, making a total of $580 per acre for logging, clearing and grubbing.

It is clear that no accurate estimate of the acre cost of removing stumps can be made until at least two elements are known: (1) the number of stumps per acre, and (2) the weighted diameter of the stumps. By "weighted diameter" we do not mean the average diameter, but the weighted average for cost estimating purposes. To illustrate, suppose there are 30 stumps per acre, 20 of which measure 12 in. in diameter at the cut-off (all diameters should be given at the cut-off and not at the ground level), and 10 30 in. in diameter. Then the average diameter would be calculated thus:

	Total diam.
20 at 12 in.	= 240 in.
10 at 30 in.	= 300 in.
30 at 18 in.	= 540 in.

If we assume that the cost of blasting stumps varies as the square of the diameter, the weighted diameter for cost estimating purposes is calculated thus:

	Total squared diam.
20 at (12 in. × 12 in.) = ...	2,880
10 at (30 in. × 30 in.) = ...	9,000
30 at nearly (20 in. × 20 in.) = ...	11,880

This gives nearly 20 in. as the weighted diameter for cost estimating purposes.

Having estimated the number of stumps per acre and their weighted diameter, it is possible to approximate the cost of blasting them out. To this must be added the cost of piling and burning them, which, it is altogether probable, can be reduced to a unit cost per stump of given size that will make accurate estimating possible. Fallen logs may be estimated in cords of wood per acre, and the cost of piling and burning them may then become a matter of quite accurate forecast.

In estimating clearing and grubbing, as in estimating any

other costs, the primary object should be to measure the work in units that are true functions of the cost. By itself the acre of clearing and grubbing is not a satisfactory unit for measuring costs. The thousand ft. board measure is a suitable unit in which to express the cost of felling trees, making them into logs and loading onto cars, wagons, etc. The stump of a given size is the proper unit in which to express the cost of grubbing stumps. The cord or cubic foot of wood may be a suitable unit in which to express the cost of piling and burning. Other units may be desirable. It is clear that existing cost data on clearing and grubbing are defective, for the most part, because they are not recorded in proper units.

Effect of Method of Excavation on Cost of Grubbing. *Engineering and Contracting*, Dec. 25, 1907, gives the following: One of the items of work to be done in grading a railroad is generally the clearing and grubbing of the land. Under some contracts and specifications this work is paid for as one item, under others as two items as clearing and as grubbing, while under other forms of contracts this work is included in that of excavation.

The method of paying for clearing by the acre as one item and grubbing as another item is to be commended. In order to do the excavation all the land must be cleared, but in addition to the area used for the cuts and embankments, the entire width of the right of way must be cleared, and overhanging trees and branches must be cut away. On the other hand there is no need of grubbing the area occupied by the embankments, nor that on the right of way not included in the cuts, hence there should be no reason why this area should be included in the payment. Likewise the method of doing the excavation will very materially effect the cost of the grubbing, while it does not play any part in the cost of clearing.

When steam shovels are used the grubbing cost is small, as these machines will undermine the stumps, causing them to fall into the pit, where they can be loaded onto the cars by means of chains, attached to the dipper teeth. This work retards the progress made by the shovel, but the cost of grubbing is greatly reduced, and a contractor could afford to bid a low price on the grubbing when done with a steam shovel, if it is not lumped in with the clearing or other work.

When grubbing is done in connection with rock excavation, its cost is small as the stumps are shot out with the blasting of the rock, and the only additional expense is to dispose of the stump. This will have to be done by hand and will be work that the contractor will charge for under grubbing.

When grubbing is done for scraper work the stumps and largest roots must be blasted and dug out, and the work is much more expensive than with rock excavation and steam shovel work, although a large railroad plow in loosening the ground will cut and break up many of the roots, so that they do not have to be grubbed.

The grubbing for elevating grader excavation must be done much more thoroughly than that for scraper work. The stumps and large roots must not only be grubbed, but all the small bush stubs and roots must also be cut out. This is necessary as the grader plow will not cut these roots, as the pull on the plow is a steady one, unlike that of a breaking plow, which can be run in jerks, while the plowman can shake up the plow, which is a considerable help. In grubbing for a grader it is not advisable to blast the stumps, as this makes large deep holes, which, after rains, become full of water and soft, thus causing the traction engine and grader to mire in these holes. For this reason where there are many stumps of 6 in. or more in size a stump puller should be used. For elevating grader work the stump puller does its work much better than blasting, as it will not only pull up the stump, but also all the large roots and many of the small ones. Nor does it leave as large a hole as a blast does. Its work is as economical as blasting, and at times is much cheaper. The small stubs and roots must all be grubbed by hand. To do efficient work of grubbing for a grader, after the large stumps have been pulled, men should be spaced a few feet apart and the entire area gone over, the men working in rows grubbing up everything that may affect the working of the grader. This makes grader grubbing more expensive than that of any other grubbing for ordinary excavation work.

Loss of Material Due to Grubbing. Mr. F. W. Harris, in *Engineering News*, Dec. 17, 1914, says that in timber country 10% of the total excavation can be considered as worthless, as it consists of humus, rock, logs, roots, etc., and another 10% should be deducted for quantities lost in blasting stumps. These percentages should be increased to 15% in each instance where excavation averages less than a 3-ft. cut. Percentages also vary with the locality. In the Bitter Root Mountains in Idaho, they would be about 5%; while on the western slope of the Cascades on the Washington and British Columbia Coast, 15% would not be too high in each case.

Estimating Shrinkage Due to Removal of Stumps. F. W. Harris, in *Engineering News*, Dec. 23, 1915, gives the following data:

The method of obtaining an estimate of shrinkage in a timber

country is as follows: Plot a trial grade line on the profile, seeing that the quantities balance reasonably close. The excavation should exceed embankment at least 10%. The profile will give the center cut and fill, and an experienced man can stand on the center line and estimate where the slopes will intersect the ground line.

The stumps in each station should be noted and recorded according to sizes and kinds of stump, also the formation of soil, whether rock, gravel or swamp. It is essential to note the kind of stumps, as some stumps will blow out much easier than others. For instance, a 4-ft. fir stump will leave a smaller hole than a 4-ft. cedar stump. This should be borne in mind merely as it would be a useless refinement to grade the loss of excavation by the kind of stump shot out. In the office the stumps should be listed according to cuts and fills.

The following table will apply on the Pacific Northwest Coast for computing loss of excavation by blowing out stumps. Fir, cedar, spruce, hemlock are averaged in the table.

6 to 12 in.	1 cu. yd. each
12 to 24 in.	3 cu. yd. each
24 to 36 in.	5 cu. yd. each
Above 36 in.	10 cu. yd. each

In swamps where the growth is spruce, hemlock, cedar, maple, 50% should be added to these quantities, as it requires more dynamite to lift a stump of given size, owing to the decreased resistance of the swamp soils. To get shrinkage, say between Sta. 20 and 30, this would average a 4-ft. cut on the center line for the entire distance. Assuming the record shows the soil to be clay and hardpan, the list of stumps for this section would total 65, divided as follows:

6 to 12 in.	20	20 cu. yd.
12 to 24 in.	20	60 cu. yd.
24 to 36 in.	20	100 cu. yd.
Above 36 in.	5	50 cu. yd.
	65	230 cu. yd.

In this cut the grade line would have to be lower to give the additional 230 cu. yd. lost in blasting. As the same condition, however, is assumed to exist in the adjacent fill, the grade line will give a correct balance.

The grubbing clause should be revised to include the following: All stumps and roots on the right-of-way to be grubbed will be paid for according to the list of sizes shown on the schedule of quantities. Stumps 6 to 24 in. will be measured 4 ft. above the ground; stumps over 24 in. diameter will be measured at the butt log or on top of stump.

Clearing and Grubbing Methods. Trees are cut down with axes and saws, cut up into saw logs, poles, ties or cord wood and removed. The remaining debris is piled and burned. Stumps can be dug out by hand, burned in place, pulled or blasted.

Digging Out Stumps is a costly operation. It is sometimes unavoidable but whenever possible some other means of removal should be sought.

Burning in Place, while often economical, is too slow a process for general use. It has the advantage of making a complete disposal of the stump at once. On very large stumps such as are encountered in the Pacific Northwest the saving in cost of disposal may justify the use of this method.

Blasting is by far the most satisfactory method of grubbing stumps prior to excavation, and if care is taken not to use too much explosive it is equally suitable for removing stumps from the base of embankments. It is a convenient method requiring no extra plant and no special skill beyond that readily acquired by the average foreman.

Amount of Dynamite Used in Stump Blasting. The following table taken from records of blasting in Minnesota, Pennsylvania, Oregon, Kentucky, Michigan and Florida is given by Mr. J. R. Mattern in a bulletin on clearing land of stumps, prepared for The Institute of Makers of Explosives. The stumps were blown out effectively and successfully and the figures should serve as a guide. The grades of dynamite used are not given.

TABLE

AMOUNT OF DYNAMITE USED IN SUCCESSFUL BLASTING

Dead Pine Stumps

Diameter and soil	Sticks of 1¼ in. dynamite or powder
10 in., Clay	1
12 " Sand	1½
12 " Loam	1
12 " Clay	1
14 " Clay	2
16 " Clay	1½
18 " Sand	3
18 " Loam	2
18 " Clay	1½
20 " Sand	7
20 " Clay	4
24 " Loam	5
24 " Sand	5½
24 " Loam	4½
24 " Clay	4
36 " Sand	10
36 " Loam	8½
36 " Clay	7½
40 " Clay	7
48 " Sand	13
48 " Loam	10
48 " Clay	9
60 " Clay	15

Green Pine Stumps

Diameter and soil		Sticks of 1¼ in. dynamite or powder
15 in.,	Loam	4
24 "	Sand	10

Dead Oak Stumps

8 in.,	Sand	1½
12 "	Sand	2
12 "	Loam	1½
15 "	Loam	1½
16 "	Clay	1½
18 "	Loam	3
20 "	Loam	3½
24 "	Clay	3
26 "	Clay	2
27 "	Sand	5
27 "	Loam	4½
30 "	Clay	4½
30 "	Sand	6
34 "	Clay	4½
38 "	Clay	5½

Green Oak Stumps

16 in.,	Clay	3

Dead Fir Stumps

30 in.,	Loam	10
36 "	Clay	12
48 "	Loam	26
72 "	Clay	36

Green Fir Stumps

40 in.,	Loam	20

Green Spruce Stumps

60 in.,	Sand	32

Dead Hemlock Stumps

15 in.,	Sand	2

Dead Walnut Stumps

10 in.,	Loam	1

Green Gum Stumps

15 in.,	Clay	3½

Dead Gum Stumps

24 in.,	Sand	4

Green Black Gum Stumps

16 in.,	Sand	5½

Green Sugar Maple Stumps

16 in.,	Sand	5½

Dead Snag

20 in.,	Sand	4½

Tap-Root Pine (Charge in Wood)

6 in.,	Sand	½
8 "	Sand	¾
10 "	Sand	1
12 "	Sand	1½
15 "	Sand	2
18 "	Sand	2½

Tap-Root Pine (Charge Against Wood)

6 in.,	Sand	1
8 "	Sand	1½
12 "	Sand	3
15 "	Sand	4
18 "	Sand	5

To blast out standing trees without first cutting them down, use about 20% more explosive than you would for the stumps. It is better to blast big trees with several charges, firing them electrically.

Costs of clearing and grubbing without description of conditions encountered and methods employed are of doubtful value. To give them here as they should be given would require more space than the subject warrants in a book of this character. The reader is referred to the author's book on "Clearing and Grubbing," in which will be found many examples of the cost of this work done under various conditions and by various methods throughout the United States.

Bibliography. "Handbook of Clearing and Grubbing" by H. P. Gillette.—"Cost Data," H. P. Gillette.

Bulletins 134 and 163 of the University of Minnesota Agricultural Experiment Station.—Bulletin 170, Washington State Agricultural Experiment Station.—Bulletin 154, Kentucky Agricultural Experiment Station.—Farmers' Bulletin 600, U. S. Department of Agriculture.—"Clearing Land of Stumps," by J. R. Mattern, for the Institute of Makers of Explosives.

CHAPTER V

LOOSENING AND SHOVELING EARTH

Methods of Loosening the Soil. There are three methods in common use for loosening earth: (1) picking, (2) plowing, and (3) by explosives. Many materials are loosened and loaded at the same time with the hand shovel, but it is almost invariably cheaper to pick or plow or otherwise thoroughly loosen any kind of earth except sand, before shoveling. Clays, when wet and tenacious, may be effectively cut with spades.

Cost of Picking. The pick is ordinarily not as economical as the plow, but it must be used in digging trenches and in other confined places. *Trautwine gives the average output per man-hour as follows; wages assumed at 20 ct. per hr.

Material	Cu. yd. per hr.	Per cu. yd.
Stiff clay or cemented gravel....	1.4	$0.146
Strong heavy soils	2.5	.08
Loam	4	.08
Light sandy soil	6	.03
Pure sand	20	.01

M. Ancelin states that a man with a pick would loosen 1.6 to 2.3 cu. yd. of earth, 0.7 to 1.1 cu. yd. of gravel, and 0.9 cu. yd. of hard pan per hour.

In loading from a high bank of hard sand into cars, it required one pick or bar man to each pair of shovelmen. Each pair of shovelmen sent out 30 loaded cars, equivalent to 30 cu. yd. per hr. It must be remembered, however, that this material while hard, was located in a high bank, and much of it was undermined or barred down, and broke by force of the fall, thus requiring very little actual picking.

High clay banks are sometimes loosened by powder, but more often by "undermining" and "falling." A narrow cut is dug into the base of a bank that is 7 to 8 ft. high, and a line of wedges is driven on top, 1 or 2 ft. from the edge; thus wedging off pieces weighing many tons, which break in falling.

Patton in "Civil Engineering" says that throwing horizontally with a shovel is limited to about 12 ft., or about 6 ft. vertically.

Comparison of Pick and Mattock. In trimming ground, *Engineering and Contracting*, Jan. 15, 1908. states that the mattock is much better adapted than the pick. This is so of parking work, as in trimming there is seldom more than an inch or two of earth to be dug and the narrow pick will not cut off as much earth at each stroke as the broader blade of the mattock. In railroad cuts, the pulling down and dressing up of slopes is done better by mattocks than by picks. Likewise in cellar and foundation work, where it is necessary to dress down a perpendicular

side of a bank to neat dimensions and lines, the mattock does better and more economical work than a pick. Thus for nearly all cases of trimming and dressing the mattock should be the tool used.

For digging, as a rule, the pick should be given the preference. At one blow with a pick a large wedge shaped piece of earth can be loosened from a bank, when the face of the wedge is free, while with a mattock a single blow will not loosen as large an amount of earth, the piece being a truncated wedge, of seldom more than half the altitude of the wedge the pick will loosen, and only about two-thirds of the base. This should always be remembered, as the most important misuse of the mattock is to use it in open cut work for digging.

The mattock can be used to better advantage than a pick for digging some few materials. This is so of very plastic clays. A pick will make but little more than a hole in material of this kind, and when it is used as a lever, this hole will simply be enlarged, but with a mattock small pieces can be pried out and large pieces can be cut out by the cutting blade. A more economical and satisfactory way of digging this kind of material than with either the mattock or the pick is with a spade. One of the editors of this paper increased the output of a gang of men nearly 30% in handling such material in a railroad cut some years ago by substituting spades for mattocks and shovels. All the work was done with one tool, and the loosening or digging was done better and cheaper with the spade.

In swampy and marshy ground the mattock is superior to the pick for digging. This is due to the fact that there are generally roots in such ground, and also because the material is generally clay of more or less plasticity. The comments that have been made regarding grubbing with a mattock show that it is the tool for digging and loosening whatever roots are encountered. It is also true that turf and peat are dug better with a mattock than with a pick.

In digging ditches and trenches a mattock is often needed until the trench is a foot or more deep, as roots are encountered and sometimes old logs and debris, but as soon as this kind of material is gotten rid of, only picks should be used. The cost is greatly increased by using mattocks. The sides of trenches can be dressed well with a pick, so that sheeting can be put in place. In open ditches the pick should be used for digging, but when a permanent slope is to be put on the ditch a mattock should be used.

The mattock is essentially a grubbing and dressing tool, and is only adapted to economical digging in a few special materials.

It may be termed a misuse of the tool to make it do digging in ordinary earth. For earth work a supply of mattocks and picks should always be provided, so that as occasions arise for the use of each they will be on hand and money will not be wasted in making a tool do work for which it is not adapted.

Cost of Picking and Shoveling. The cost of loosening with a pick, and shoveling into wagons when wages are 20 ct. per hr. is as follows:

Kinds of Earth	Cu. yd. per hr.	Per cu. yd.
Easy earth, light sand or loam....	1.25	$0.16
Average earth	1.00	0.20
Tough clay	0.75	0.27
Hard sand	0.375	0.53

Shoveling. By vigorous exertion a man may shovel 1 cu. yd. ("place measure") of light loose earth into a wagon in 12 or even 10 min., or at the rate of 50 or 60 cu. yd. in a 10-hr. day, using the ordinary round-pointed shovel. A man can sprint 100 yd. in 10 sec. or at the rate of 20 miles an hour, yet no one would expect a continuance of the performance all day long. Short-time observations, where a man is working vigorously, should therefore not be made the basis of an estimate of average cost, as is not infrequently done. Trautwine speaks of the "lost time" of shovelers as being ordinarily about 4 hr. out of 10. The expression is misleading, for time spent in rests between the arrival of teams is not time lost, provided the foreman insists upon vigorous exertion while actually working. A man may shovel only 20 min. out of an hour, yet accomplish exactly as much in a day as another man shoveling steadily. Bear in mind that men need not be kept steadily busy, provided that when they do work they make up for the time "lost" in resting; and the same is true of horses.

In this connection it is very interesting to note that if reasoned out "theoretically," as machine work frequently is by inventors and over-sanguine manufacturers, the output of a plow should be many times what it actually is, using "conservative figures" thus: The ordinary plow cuts a furrow 6 in. deep by 12 in. wide, so that a team traveling at the very slow speed of 1⅛ miles an hr. (less than half its ordinary walking gait) would loosen 110 cu. yd. an hr., while if it walked right along at its usual gait the amount would be 220 cu. yd. loosened per hr.! There has been too much of such "theory" used in estimating the cost of earth work.

It may be said that, roughly speaking, about 175 shovelfuls of earth thrown into a wagon box form 1 cu. yd. If we assume average earth to weigh 100 lb. per cu. ft., we find that an

TABLE OF COST OF DIGGING AND SHOVELING

(Wages 20ct. per hr.)

	Cu. yd. per man-hr.	Ct. per cu. yd.
Mud into wheelbarrows (1)	0.8	25.3
Gravel into wheelbarrows (1)	1.7–2.7	9.3
Earth into wheelbarrows (1)	1.6–4.8	6.7
Earth into wheelbarrows average (1)	2.2	9.3
Earth into wheelbarrows (2) (10 miles Erie Canal)	2.8	7.0
Earth (all kinds) into wagons (3)	2.1	10.0
Earth (all kinds) into wagons (4)	2.0	10.0
Sand into cars from high face (5; 10,000 cu. yds. (place measure)	1.8	11.0
Gravelly soil into wagons after plowing (5) (20,000 cu. yds. in embankment)	1.3	15.3
Iowa soil (6)	1.5–2.0	11.3
Iowa soil (A rush job) (6)	2.8	7.1
Clay and gravel into carts (7)	1.0	20.0
Loam into carts (7)	1.2	16.7
Sandy earth into carts (7)	1.4	14.3
Loose sand into carts (8)	2.0	10.0
Clay, tenacious, excavated with spade (8) (Spaded out and handled with forks	1.25	16.0
Loosened hardpan into low dump cars (9)	1.5	13.3
Loosened average earth into dump cars (9)	1.75	11.4
Heavy black clay, wet, cast 5 to 10 ft. (10)	0.33	60.0
Loading hardpan into carts after picking (10) (Picking done at rate of 0.6 cu. yds. per man hr. Not enough pick men)	0.5	40.0
Excavating sandy gravel and stiff clay; wet (10)	0.33	60.0
Excavating dry sandy clay (10) (Earth rehandled 3 and 4 times. Inefficient foreman)	0.2	100.0
Shoveling quicksand into buckets (11) (Coffer dam excavation, 2 men to a bucket)	0.21	95.2

Authorities (1) M. Ancelin; (2) Gillespie; (3) Cole; (4) D. K. Clark; (5) Gillette; (6) J. M. Brown; (7) E. Morris; (8) G. A. Parker; (9) Lyons; (10) *Engineering and Contracting;* (11) *Eng. Record.*

average shovelful contains approximately 15.5 lb. At a good steady gait, 7 shovelfuls are loaded per min. where the vertical lift is about 5 ft. In casting for a vertical lift of 10 ft., however, only about 5 shovelfuls are handled per min. In casting earth horizontally, we may count on 9 shovelfuls per min. for a 5 ft. horizontal cast, and about half as many for an 18 or 20 ft. horizontal cast. With wages at 20 ct. per hr., it will cost about 6.67 ct. to carry a cu. yd. 10 ft. in shovels.

The amount of earth that a man will handle per hr. with a shovel varies not only with the character of the soil, but with the method of attack. If a man is shoveling from a face of earth over a foot high, one that he can readily undermine with a pick, for example, he can load into wagons 1.8 cu. yd. an hr. on an average; while if he is shoveling plowed soil, where he must use more time to force the shovel down into the soil, his output will be about 1.4 cu. yd. per hr. If he is shoveling loose earth off boards upon which it has been dumped, his output is about 2.5 cu. yd. per hr.

At a meeting of the *Connecticut Civil Engineers' and Surveyors' Association*, Jan. 8, 1901, Mr. G. A. Parker, Supt. Keney Park, Hartford, Conn., gave the following as the results of his experience:

The bank was loose sand requiring neither picking nor plowing. Material was shoveled into two-horse carts holding 1 cu. yd. It is not stated whether the measurement was of loose sand in carts or packed sand in bank, but apparently measurement was made in carts. It required 150 shovelfuls to make a cu. yd., and a man by shoveling 25 sec., then resting 25 sec., would average 5 shovelfuls loaded in 50 sec., or 22.8 cu. yd. in 10 hr., after deducting 5% for waste time. Each man counted his shovelfuls, and was allowed to cast only 5 shovelfuls before the team moved on. There were 15 shovelers in a gang and two gangs in the pit.

Mr. Parker claims that the results justify his statement that this is the best known method of working men, as it gives them needed rests, and keeps their minds active. It may be observed that it might not work so well where soil is tough, and that just as high outputs have been obtained by the common methods where sand was loaded.

Size of Hand Shovels. This is an important subject and the one which has received almost no attention from contractors and engineers. It seems to be the custom, sanctioned by long usage, to use a shovel of the size known as No. 2 or No. 3. From data presented by Mr. C. W. Hartley, in *Engineering and Contracting*, Mar. 31, 1915, Mr. Hartley finds that a No. 2 shovel holds but 13 lb. of earth and 14.5 lb. of sand; and a No. 3 shovel, 15.5 lb. of earth and 17 lb. of sand. Observations of Mr. F. W. Taylor show that the proper sized shovel for the average man contains 21 lb., and, on that basis, Mr. C. W. Hartley made some interesting experiments, working with shovels as follows:

In a gang of 38 men working in a trench, with shovels furnished by themselves, it was found that 92% were using the smallest sized shovel on the market, No. 2, while the remainder were using the next size larger, No. 3. These shovels are incapable of holding the amount of material that should constitute a shovelful. It was further observed that 50% of these men were using shovels which were worn down at the bottom, within 3 in. of the point, or until only half of the original blade remained. The loss for each shovel was estimated. By careful time observations it was demonstrated that the men using the worn shovels worked no faster than those using the good; further that men will shovel at approximately the same speed, whether they are working with a No. 2 shovel or a No. 4, and, as a gen-

eral rule, will fill the blade full whenever possible to do so. This being the case, it is self-evident that the use of small or worn shovels will entail the handling of less material.

A No. 2 shovel in good condition was found after many trials to hold, as an average load, 13 lb., the material being common loam, loose and dry. The same size shovel, worn down such as were used by half of this gang of 38 men, were found to hold but 7 lb. of earth or loam, which is, as will be noticed, only one-third of the amount Taylor has shown to be productive of the greatest shoveling efficiency.

Now let us assume that these 38 men were paid at the rate of 20 ct. per hr., or $1.80 per day, and that 13 lb. represents the unit basis from which their output is figured. Fifty per cent, or 19 of the men were using worn shovels, and were doing but 7/13 of the amount of work done by the remainder. Figured in terms of money, this would give a loss of 82 ct. per day per man, or $15.77 per day for the entire gang, or 41.5 ct. per day for each shoveler in the gang of 38 men. It is easily seen how these figures would be increased if figured with 21 lb. as the unit. For instance, if a man is shoveling with a shovel holding but 7 lb. of earth, when he might use one holding 21 lb., he is therefore performing but one-third of the amount of work that might be accomplished by him, were he provided with the proper tool. If he is a $1.80 man, engaged in shoveling all day, this means a loss to his employer of $1.20 per day.

These same data were obtained for shovels of other sizes, No. 3, No. 4 and No. 5, and from these foregoing described experiences Mr. Hartley determined to use No. 4 shovels.

It has also been the custom, particularly in eastern states, for the contractor to allow the laborers to furnish their own shovels. This is a grave mistake, as laborers are naturally inclined to use the smallest sized shovel, and each will furnish a shovel of but one shape; whereas it is generally economical to use a shovel of different shape for each kind of work, and of different size for each kind of material. The argument against furnishing shovels for the men has been that many are lost or stolen. Mr. Hartley presents a report showing the number of shovels in use, and those lost and worn out during the season starting Apr. 15, 1914, and ending Nov. 10, 1914. In this season of 168 working days, 756 shovels were furnished the men and 353 shovels were used up, an average of 2.1 per day. These shovels were of two different grades, costing $8.60 and $5.25 per dozen. Assuming that each shovel cost 72 ct. apiece, or at the rate of $8.60 per dozen, the cost for supplying No. 4 shovels for laborers was $1.51 per day. The average number of laborers at work daily was 178, and the

cost of the shovels was less than 1 ct. per man per day. Of the 353 shovels used up, 308 were worn out, and 45 were unaccounted for, being lost, stolen or broken. It would seem that this small percentage of 12.7 unaccounted for would tend to refute the argument that many shovels are lost and stolen.

From the foregoing the reader must not infer that a No. 4 or No. 5 shovel is best for all work. On the contrary, the size and shape of the shovel must be suited to the hardness and tenacity of the soil, as well as its weight and other characteristics; for example, in tough soils a round-pointed shovel that will easily penetrate must be used, while for handling loose earth or in shoveling sand, unless it is to be cast some distance, it is folly to permit the shovelers to use any but large, square-pointed scoops. With a large square-pointed scoop, a strong man can, for a short time, load sand into a wheel-barrow at the marvelous rate of 5 min. per cu. yd. On any work where various kinds of material are handled, several sizes and shapes of shovels should be supplied. This is contrary to the usual practice as evidenced by an interesting example noted in *Engineering and Contracting*, Apr. 7, 1915. At a point where steam railway tracks were being elevated over a street, carrying a double track trolley line, three different gangs of laborers, representing three different interests, were engaged in excavating hard yellow clay with hand tools. The steam railway gang excavated for a bridge abutment, the water pipe extension gang excavated for the lowering of a large main, and the street railway gang excavated for track depression. Each gang used the ordinary square-pointed shovel, commonly used in mixing concrete by hand. It was not at all uncommon for a laborer to work diligently for at least a minute in sinking his shovel into the clay the full length of the blade. To do this, much "pumping" of the shovel handle and much pushing with the foot was necessary. This black clay was the same as that lying under the black top soil of the Illinois prairie. In digging ditches used for tile draining, farmers uniformly use a long narrow bladed spade, locally known as a "tiling spade." This spade is referred to in some localities as a "sharp shooter." In the soil mentioned, one or two thrusts by the foot will stick it in to its full length. Spades of this type should have been used on the excavating operations above mentioned.

Scientific Management in Trenching. *Engineering and Contracting*, Nov. 29, 1911, gives the following:

The laying of mains and services for a gas works offered the most prolific field of investigation to begin with, since more than 400 men were engaged in this kind of work. With the aid of a stop watch and note book the following data were gathered:

Laborers digging 9 ft. sections of 3.23 cu. yd. each.

Laborer No.	Min. per cu. yd.
1	75.8
2	62.0
3	83.6
4	72.7
5	72.7

The time for removing this dirt was much too slow, and this for the following reasons:

1. The working capacity of the different men varies greatly due to lack of experience, old age, and a slow natural gait acquired by years of such work.

2. Good men, natural-born workers, and capable of much work, are slowed down or work at the pace set by the men next to them.

3. Men will "soldier" at every opportunity. They will work at a reasonable gait while the foreman stands over them and watches them, but just as soon as he turns his back and leaves the gang, the men will "soldier." The foreman purposely picks a crew of mixed nationalities so as to avoid "soldiering" and waiting for each other as much as possible.

Two days later, after spending most of the time with the gang, 14 10-ft. sections were laid off, and the men timed on each section, with the results given below:

Laborer No.	Time per cu. yd.
1	55.1
2	69.3
3	66.5
4	42.2
5	38.2
6	37.0
7	62.5
8	62.5
9	62.5
10	63.7
11	63.7
12	72.2
13	75.0
14	71.0

The average time was 60 min. per cu. yd. The two men digging sections 4 and 5 are good men and work fast. They could easily earn \$2.50 per day on the basis of \$2 for the average man. All the men knew they were being watched closely, and worked more steadily than they otherwise would. Of course, there is always some variation in soil, and temperature conditions have a good deal to do with the manner in which the men work. It grew hotter in the afternoon, and the men naturally weakened a little.

Similar observations were made with another gang working on the laying of a 4-in. main on Cameron Ave., north of Woodland.

Number of hr. digging: 84. Yd. of dirt removed: 86.85 = .967 hr. or 58 min. per yd. as the average of 17 men digging.

When I came to this job I told the foreman that I was doing some inspecting for the Street Department. When he saw me taking notes in my book and frequently looking at my watch, he began to push the men along, muttering to them in their own language, most of them being Polish. He complained about the short run jobs, and said it was difficult to know how to place his men. The soil here is softer than that on Jefferson Ave., but wet and heavier below the first foot or two. In two different places the banks caved in in the same half block, while nothing like this happened on Jefferson Ave. in about four blocks or more.

Ratio of Time Required to Dig and Throw One Shovelful of Dirt to the Time Required to Backfill One Shovel of Dirt. Allowing for variation in soil of section by considering the section as composed of ⅓ soft soil and ⅔ harder soil, and multiplying observed times by this ratio:

On Jefferson Avenue, 1 ft. below surface:
Mean time per shovel ....11.5 sec.
Do., 3 ft. below surface:
Mean time per shovel ....16.41 sec.

$$11.5 \times \tfrac{1}{3} = 3.83$$
$$16.41 \times \tfrac{2}{3} = 10.95$$

14.78 sec. per shovel

Mean of 51 other observations taken at random, 13 sec. per shovel. Average of the two (about), 14 sec.:

Time per shovel on backfilling:
8-in. main gang (mean of 180 observations), 5 sec.
4-in. main gang (mean of 190 observations), 4.8 sec.

$$\frac{\text{Time required to dig} \ldots\ldots\ldots\ldots 14}{\text{Time required to backfill} \ldots\ldots\ldots\ 5} = 2.8$$

or a yard of dirt should be thrown back in .357 times required to dig it.

Taking the following as the average cross-section: One cu. yd. = 33.4 lin. in. or .928 lin. yd. Total time required to dig and backfill .928 yd. of ditch of the above section = 59 min. digging + 16.5 min. backfilling, or 75.5 min. per cu. yd.

Digging of the Average Man Under Close Supervision. Soil rather hard, and ditch located about 5 ft. from row of trees. Digging in the morning:

(1) Average time per yd. for good men, 47.3 min.
(2) Average time per yd. for average men, 57.4 min.
(3) Average time per yd. for good men with bonus, 38.3 min.
(4) Average time per yd. for good men without bonus, 59.3 min.
(No. 1 is the average of No. 3 and No. 4.)

Amount of work done by bonus men was 1:51 times work done by average man. This is equivalent to $3.03 on a basis of $2 per day. The bonus allowed was three hours' overtime, making the day's pay $2.60 instead of $2. On the basis of 60 min. for the average man and 40 min. per yd. for the bonus man, the men would be doing an excellent day's work. Even allowing this bonus for work at the rate of 45 min. per yd. ($2.66 on the basis of $2) would pay because of the influence of the good men on the other men.

The Design of Shovels. Fig. 1, given in *Engineering and Contracting*, Aug. 18, 1909, shows a method of testing shovels. A cord was suspended from a spring scale to the handle at the point

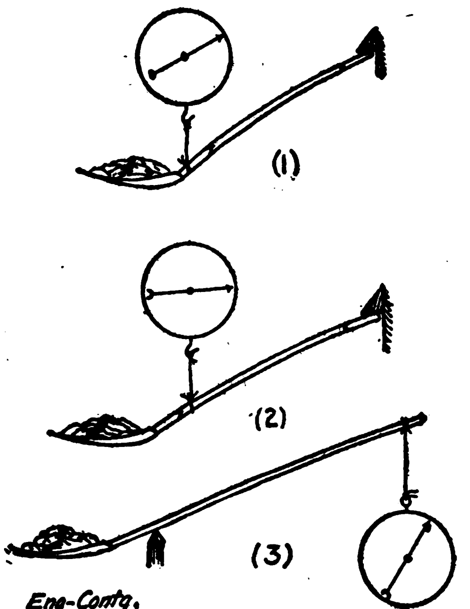


Fig. 1. Sketch Showing Method of Determining Efficiency of Shovels.

the workman usually grasps in lifting. The distance from the end of the handle to the point of suspension was the same in all cases. This then brought the hand some distance from the bowl with long handles and very close to the bowl with short handles. The bowls were loaded and the spring scale showed that the shorter the handle the greater the load on the bowl with a certain weight read on the dial which meant the shorter the handle the greater the load with the same effort. The inclination of the handle to the bowl also cut considerable figure. The experiments would indicate that for lifting and turning, the shovel to use should have a rather short handle with a pretty large angle from the line of the bowl.

Such a shovel should be good for handling loose coal, broken stone, gravel and for concrete mixing. The bowl is a trifle larger than the ordinary No. 2 shovel, is flat and is slightly concave on the lower side for half its length. The object of this is said to be to furnish stiffness when occasional spading is done, to furnish an angle to make the front edge self sharpening and to prevent the suction so often experienced in handling soggy earth.

Types of Shovels. Of the many types of shovels manufactured the following are designed for use on earthwork. Prices given are those in effect prior to the war.

Nursery Spades cost $11 per doz. *Ditching Spades* and *Concave Drain Spades* 14 to 18 in. long, cost $9 per doz. *Post Spades* cost $12 per doz. and *Marl Gouges*, 10 to 14 in. long, cost $5 to $7 per doz.

Hand Shovels. Net prices for standard railroad contractors' and mining shovels, at Chicago, in quantities, are as follows with prices for four grades: (1) Extra grade made of best crucible steel, finely finished with best white ash handles; (2) first grade shovels, also made of crucible steel, and grades (3) and (4) made of open hearth steel. The net prices in Chicago on these four grades are as follows:

PRICES AND SIZES ON HAND SHOVELS

Size	Size Blade, Width (in.)	Size Blade, Length (in.)	Extra Grade per doz.	1st Grade, per doz.	2d Grade, per doz.	3d Grade, per doz.
2	9½	11¾	$8.91	$7.83	$6.48	$5.70
3	9¾	12¼	9.18	8.10	....	....
4	10½	12½	9.45	8.37	....	....

The above prices are for black finish; for polished add 50 ct. per doz. Shovels with square or round points, "D" or long

Fig. 2. Nursery Spade.

Fig. 3. Ditching Spade.

Fig. 4. Concave Drain Spade.

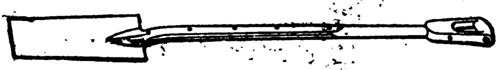


Fig. 5. Post Spade.

Fig: 6. Marl Gouge.

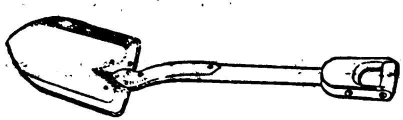


Fig. 7. D Handle Round Point Shovel.

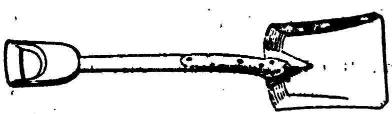


Fig. 8. D Handle Square Point Shovel.

handles are all the same price. The size No. 2 is the one commonly used. For sewer or brick shovels made in No. 2 size, but having a shorter and heavier blade for clay and other heavier material, net prices are as follows:

	Each	Per Doz.
Extra grade	$1.00	$10.00
Second grade	.648	6.48

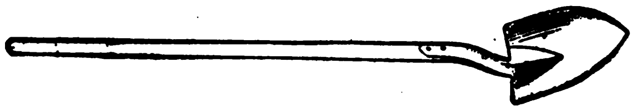


Fig. 9. Long Handle Round Point Shovel.

Fig. 10 shows a scoop for breaking down from the top of cars and getting to the bottom when a square point scoop will not work.

Fig. 10. Diamond Point Scoop.

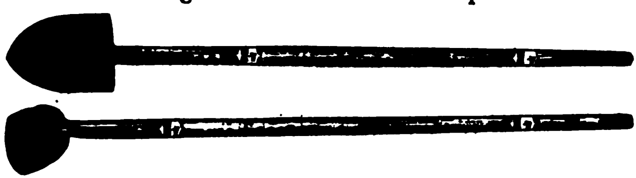


Fig. 11. Telegraph Shovel and Spoon.

Cost Data on Hand Excavation. **Mr. John F. Ely, in *Engineering and Contracting*, June 19, 1907, gives some observations on the cost of excavating earth. The following examples were observed.**

1. Six men excavated a square hole containing 15 cu. yd. in 6 hr., or at the rate of 0.4 cu. yd. per man hr.

2. A gang averaging 4.5 men dug a trench 3.5 by 5 ft. deep, 370 cu. yd., in 25 hr., or at the rate of 0.42 cu. yd. per man hr.

3. A gang excavated for a cellar 5 ft. deep, 1,029 cu. yd., 5,840 labor hr., or at the rate of 0.69 cu. yd. per man hr.

4. Four men excavated for a man-hole, 79 cu. yd. in 60 hr., or at the rate of 0.33 cu. yd. per man hr.

5. Ten men excavated for a sewer 111 cu. yd. in 36 hr., or at the rate of 0.30 cu. yd. per man hr.

6. A gang excavated a trench, 8 ft. wide by 4 ft. deep, containing 193 cu. yd. in 418 labor hr., or at the rate of 0.47 cu. yd. per man hr.

7. A gang excavated for a cellar containing 1,603 cu. yd. in 6,400 labor hr., or at the rate of 0.47 cu. yd. per man hr.

8. A gang excavated for a sewer trench, 3 ft. wide by 5 ft. deep, containing 137 cu. yd. in 259 labor hr., or at the rate of 0.53 cu. yd. per man hr.

Total 11,415 labor hr., 26,538 cu. yd., or at the rate of 0.57 cu. yd. per man hr.

In the third case, the earth was partially loosened by plowing, and partly by pick, and shoveled directly onto wagons. In the fourth and fifth cases the small amount was due to the depth and narrowness of the excavation, some shoring being necessary, and a part of the earth being hauled twice.

Cost of Handlng Ore. Mr. H. E. Scott, in the *Journal of the Worcester Polytechnic Institute*, states that in unloading ore at the Lake Erie dock the shovelers were paid by the ton, and that the following records have been made:

The prices paid were 13 ct. per ton on straight work, and a maximum of 18 ct. per ton for cleaning up, after 80% of the cargo had been removed by automatic machines. Men working at the 18 ct. rate have earned as high as $12 per day of 10 hr., which means 6.67 tons of ore were shoveled in one hour. Working at the 13 ct. rate with eight men in a hold, shoveling into one ton bucket, each man can handle 5 to 6 tons of ore per hr.

Loosening and Shoveling Sticky Clay. *Engineering News*, Sept. 27, 1890, contains an interesting note on the methods used for loosening and shoveling clay in the St. Clair Tunnel, Chicago. The clay was known to be soft, and no difficulty was anticipated in digging it, but in this very soft tenacious clay lay the root of the trouble. Had the clay been stiff and dry, it could have been dug with pick; but it was permeated with water, and in tenacity it is said to have borne some resemblance to India rubber. An ordinary shovel was bent out of shape prying into the

sticky mass, and even spades were soon doubled up. The spade illustrated in Fig. 12 was tried, but the progress made with this tool, however, was discouragingly slow, for the clay had to be pried out in chunks. On the average, one gang of 26 men could dig out about enough in 8 hr. to advance the shield 2 ft.; a creditable enough advance perhaps, and yet aggravatingly slow.

Before the tunnel had progressed very far, a carpenter, or joiner, secured employment as a laborer in the excavating gang. He had never been accustomed to working with a shovel or spade, but with the draw-knife. The next time he reported for work he carried an arch-shaped draw-knife, made of a piece of heavy band iron, bent to a half circle about 6 in. across, with eyes at each end in which wooden handles were stuck. The lower side of the

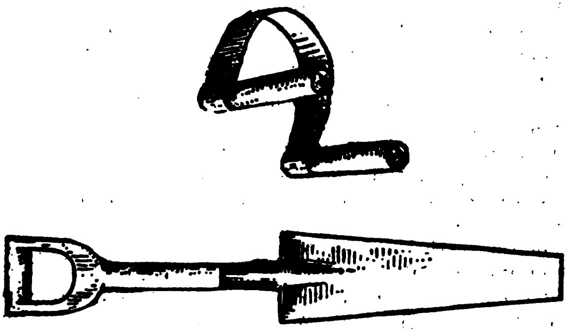


Fig. 12. Spade and Scraper Used in Tunneling in Clay.

band was brought to a cutting edge. With this novel style of draw-knife he went to work and was able to shave the clay down twice as fast as it could be chopped out with the spade. All the men were soon supplied with the new tool, and from that time forward the rate of progress of the excavation was materially increased.

In connection with work in this kind of material, it is well to note that in ordinary Chicago clay, a man with a spade should excavate 10 cu. yd. per day of 8 hr. This kind of clay is best rehandled with forks after it has been spaded out of place. In shoveling stiff clay with shovels, the rate of progres can be increased by dipping the shovel in water between each shovelful. In shoveling sticky mud, if a few holes are drilled in the blade of the shovel so as to allow air to penetrate between the mud

and the shovel blade, the suction will be reduced, and the mud will slip more easily off the bowl.

The Cost of Digging a Cess Pool. *Engineering and Contracting*, Oct. 28, 1908, gives the following:

The hole was dug on Long Island in a clay material with an occasional boulder. The material was stiff enough to stand up without shoring. The hole was 8 ft. in diameter and 24 ft. deep. For two days two men did the work, but, when a bucket had to be used, another man was added to the force. A three-legged derrick, with a crank on it, was used to hoist the bucket of earth. The excavation was made entirely with picks and shovels. There were 1,305 cu. ft. of material excavated, or about 48 cu. yd. A 10-hr. day was worked. The cost of the work was as follows:

2 men 2 days at $1.50	$ 6.00
3 men 5 days at 1.50	22.60
Total	$28.50

This gives a cost of 60 ct. per cu. yd. for excavating and hoisting the material and dumping it on the ground by the side of the hole. This cost is quite reasonable for this sort of work.

Cost of Picking and Shoveling Hardpan. (*Engineering and Contracting*, Dec. 16, 1908.) In a clay cut on some railroad work in Ontario Co., Ontario, Canada, some cemented gravel or hardpan was encountered. The bed of gravel lay along the bottom of the cut, and the part to be excavated was from 0.8 ft. to 4 ft. in depth. The cemented gravel was so hard that a pick, handled by an experienced man, would only enter it about 1½ in., but the extent of the work was so small that the contractor did not feel justified in purchasing a pick pointed or rooter plow.

To excavate this hardpan with picks and shovels required 4 pickers to 5 shovelers, and 1 man was used on the dump. Wages were 15 ct. per hr. The extreme haul on the excavated material was 1,000 ft. At first 4 carts were used but the hauling was finished with 6 carts, at 18 ct. per hr.

In all 500 cu. yd. of hardpan were moved at the following cost per cu. yd.:

Shoveling	$0.304
Loosening	0.245
Dumping	0.030
Hauling	0.195
Total per cu. yd.	$0.744

This is a high cost, although the allowance of 18 ct. for carts per hr. is small. The pickers loosened about 6 cu. yd. per day of 10 hr., while the shovelers shoveled 5 cu. yd. per day per man. This

is a low record for shoveling, but as the layer of gravel was thin it was no doubt difficult to keep enough muck loosened to allow the men to get a good shovelful as they worked. Although the cost of loosening is nearly one-third of the total cost, yet the cost per cu. yd. may have been reduced by using some extra pickers, thus allowing the shovel men to make a greater output.

A Rating Table for Excavating with Pick and Shovel. Mr. L. T. Sherman, in *Engineering and Contracting*, May 27, 1914, presented a novel method of rating the probable amount of excavation that can be done with pick and shovel in various materials. This article follows in full:

The accompanying diagram and tables represent the amount of excavation of various materials which will be performed in a 10-hr. day by the average laborer working under good supervision. In making this compilation the writer has compared a large number of data from many sources with figures obtained in his own experience on construction. As might be expected there is wide divergence in such published data.

The curves in the diagram are based on a rational relation of one class of material to another as regards the amount of work or power required in picking or shovel cutting and the power required in casting up materials of different weights. The output of excavation is proportional to the amount of power or work required to move a cubic yard of the material. Let the amount of work or power to cut into and fill the shovel with sand be called unity. Then for other materials the relative power to cut out and place on the shovel will from experience be as in Table I.

TABLE I.—POWER TO PICK, LOOSEN AND CUT ONTO SHOVEL

Sand	P = 1.0
Gravel, loose	P = 1.5
Earth, medium	P = 2.0
Clay, light	P = 3.0
Clay, dry, hard	P = 4.5
Clay, wet, heavy	P = 5.0
Hardpan	P = 6.0

The work or power to lift or cast up the material after the shovel is filled is proportional to the weight of material and height cast or, which is the same, the depth of cut. Then if *W* is the weight, the relative power to cast up material to different heights *H* will be as follows:

Sand	W H where W = 1.0
Gravel	W H where W = 1.0
Earth, medium	W H where W = 0.8
Clay, light	W H where W = 1.1
Clay, dry	W H where W = 1.1
Clay, wet	W H where W = 1.3
Hardpan	W H where W = 1.12

The total power to shovel and cast any material is $P + W H$. The output is inversely proportional to the power or work required. The output of any material by hand excavation in cu. yd. per man per 10 hr. is

$$\text{Cubic yd.} = \frac{30}{P + .3\,W\,H}$$

The constants 30 and .3 are empirical, and like the relative values of P have been selected to correspond with the best data available on excavation of various materials at different depths of cut.

The curves in the diagram Fig. 13 are platted according to the above formula with coefficients P and W as previously noted. The letters represent observations from various published statements and are not equally reliable or comparable. The curves do not attempt to average the data but correspond with the writer's experience and some of the most definite of the published data.

Table II shows the number of cu. yd. an average laborer should excavate and cast out, at various depths in 10 hr. while working

TABLE II.—CUBIC YD. PER MAN PER 10 HR. AT STATED DEPTHS

	0 ft. to 3 ft.	3 ft. to 5 ft.	5 ft. to 8 ft.	8 ft. to 10 ft.	10 ft. to 15 ft.
Sands	21.2	14.5	10.7	8.5	5.2
Gravel, loose	15.4	11.8	9.2	7.7	4.9
Earth	12.8	10.5	9.0	7.5	4.9
Light clay	8.9	7.3	6.0	5.2	3.8
Dry clay	6.4	5.3	4.7	4.1	3.2
Wet clay	5.4	4.7	4.2	3.5	2.7
Hardpan	4.6	4.2	3.7	3.3	2.7
Average	10.7	8.3	6.9	5.7	3.9

at the depths stated. Table III shows the average number of cu. yd. per 10-hr. day that an average laborer should excavate working from the surface to the depth stated. This figure for the same material is naturally somewhat greater than given in Table II. These figures may be increased by 30% for rapid workers and may be decreased 30% for inefficient workmen. The foregoing material may be now definitely classified as follows:

Sand. Weight, 3,000 lb. per cu. yd. slightly damp. In natural bed. Not over 15% clay.

Gravel. Weight, 3,000 lb. per cu. yd. Loose, as excavated material.

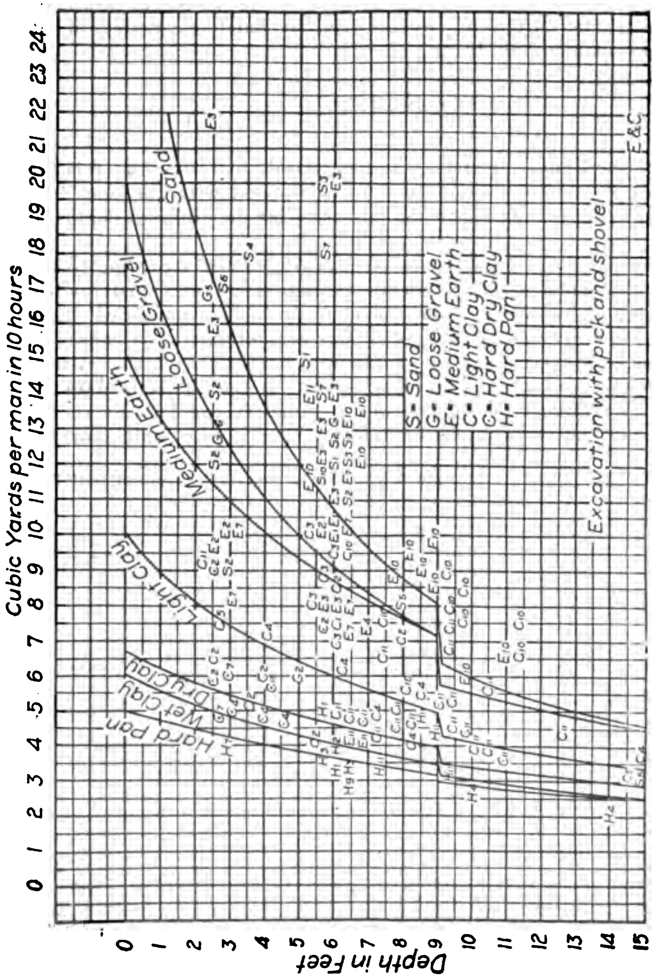


Fig. 13. Diagram Showing Amount of Excavation in Various Materials Possible in a Ten-Hour Day.

TABLE III.—AVERAGE EXCAVATION IN CU. YD. PER 10 HR. FOR CUTS FROM SURFACE TO STATED DEPTHS

	0 ft. to 3 ft.	0 ft. to 5 ft.	0 ft. to 8 ft.	0 ft. to 10 ft.	0 ft. to 15 ft.
Sand	21.2	18.1	15.1	13.6	10.7
Gravel, loose	15.4	13.7	11.8	10.8	8.8
Earth	**12.8**	**11.7**	**10.5**	**9.7**	**8.1**
Light clay	8.9	8.1	7.3	6.7	5.8
Dry clay	6.4	5.9	5.4	5.1	4.5
Wet clay	5.4	5.1	4.7	4.4	3.8
Hardpan	4.6	4.4	4.2	3.9	3.5

Earth. Weight, 2,400 lb. per cu. yd. Slightly damp, in natural bed, easily plowed, little or no pick work required. Would require some sheeting in trenches over 6 ft. deep.

Clay (light). Weight, 3,300 lb. per cu. yd. Slightly damp, easily plowed. Not stiff or very cohesive, corresponds to yellow clay lying below the black soil and above the blue clay in vicinity of Chicago. Would require some sheeting in trenches over 6 ft. deep. Little pick work required.

Clay (dry, hard). Weight, 3,300 lb. per cu. yd. Requires pick work equal to one-third time spent in shoveling and casting. No sheeting required at any depth. Corresponds to material on top of ravines along the lake shore in Lake County, Ill. Hard plowing. Adobe in this class.

Clay (wet). Weight, 3,900 lb. per cu. yd. Tough and cohesive, has to be cut out in pieces. Slightly sticky, would require substantial sheeting. Corresponds to the underlying "blue clay" of Chicago. Gumbo in this class.

Hardpan. Weight, 3,360 lb. per cu. yd. Requires picking equal to one-half the time spent in shoveling and casting.

The use of the relative coefficient P is suggested as a simple and definite means of describing or designating any class of earth excavation.

The jog in the curves (Fig. 13) at depth of 9 ft. represents an allowance of $P = 1$ on account of extra labor of shovel cutting done in recasting from a platform. As a matter of fact no recasting may be done at the 9-f depth or even 14-ft. depth, but the output per man will not be increased over the quantity shown by the diagram.

The recorded data platted on Fig. 13 are designated by a letter for the class of material. The number following the letter refers to the source from which the data were obtained, as follows: (1) "American Engineers' Pocket Book"; (2) "Handbook of Cost Data," Gillette; (3) "Earthwork," Gillette; (4) L. K. Sherman;

(5) Windette, *Journal West. Soc. Engrs.;* (6) "Concrete Costs," Taylor & Thompson; (7) Orrock; (8) Prelini; (9) *Engineering and Contracting* (December, 1908), "Atlantic, Iowa, Sewers," M. A. Hall; "Centerville, Ia., Sewers," M. A. Hall; (10) *Engineering and Contracting;* (11) *Engineering and Contracting.*

From the output recorded by Mr. Sherman in the foregoing statement, we have deduced the outputs in average material at depths of from 0 to 6 ft., 6 to 12 ft., 12 to 18 ft., and over 18 ft. These averages are presented in Table IV, together with averages of the outputs as given by Mr. Windette, given in the chapter on trenching and with those of the author, given in the same chapter. These average outputs, recorded by different engineers in widely separate parts of the country, compare very well. For a depth of from 12 to 18 ft. the average as noted by the author seems to be too high. This may be accounted for by the fact that this work was done under first class supervision and under other favoring conditions.

TABLE IV, CU. YD. EXCAVATED PER MAN HR. WITH PICK AND SHOVEL IN AVERAGE MATERIAL

Depth in ft.				Authority
0–6	6–12	12–18	18 +	
0.923	0.737	0.638		Author
1.050	0.720	0.370	0.260	Windett
0.950	0.630	0.390		Sherman

In average materials the output per man-hour may be expected to be as follows:

For depths of from 0 to 6 ft., 1 cu. yd.
For depths of from 6 to 12 ft., 0.7 cu. yd.
For depths of from 12 to 18 ft., 0.4 cu. yd.
For depths over 18 ft., 0.26 cu. yd. and less.

Conclusions. From the foregoing data we may draw some practical conclusions; for example: (1) Men should be close enough to the wagon or other vehicle being loaded not to be required to take even a few steps before casting. (2) The farther away a man is from a wagon, the less number of shovelfuls he can cast in a given time. (3) As each shovelful is also smaller, a man 12 or 15 ft. away from a wagon will load about half as much as if he were only about 4 or 5 ft. from it. Therefore, in loading wagons, it does not pay to crowd men around it; no more than six should be allowed. (4) Large shovels should be used. (5) Men should work to a face wherever possible. (6) A temporary floor should be laid down, so that the earth will fall on the floor, from which it can be more easily shoveled. (7) A high bank should be undermined with picks, and wedged off or blasted off

the top. (8) Picking should never be resorted to when plowing can be used. (9) When earth is loosened, by whatever means, it should be loosened thoroughly.

Cost of Casting Clay for Filling in Behind Retaining Wall. (*Engineering and Contracting*, Jan. 22, 1908.) Some earth had to be cast behind a low retaining wall. The work was done by company forces, the foreman being paid $2.50 per day of 10 hr., and men $1.50. The material was a heavy black clay with a large amount of vegetable matter in it, and very wet. The men did not have to stand in the water, except in a few places, but their shovels were frequently submerged. The soil was excavated to a depth of from 12 to 18 in., and at high tide there was always water in the holes that were being dug. Most of the material was spaded, but where roots and similar material were encountered, mattocks were used to loosen it. The earth was cast from 5 to 10 ft., and the bank was made about 4 ft. high. The work was hard and difficult. The material stuck to the shovels, and the water disintegrated the clay, causing a man to make several attempts to get a fair shovelful when he was shoveling where there was water.

About 16 men worked under a foreman. The work was done in the early part of the winter. In all 522 cu. yd. of excavation, place measurement, was made. The cost per cu. yd. was:

Foreman at 25 ct. per hr.	$0.043
Men at 15 ct. per hr.	0.454
Total	$0.497

This meant that one man loosened and shoveled in a day about 3⅛ cu. yd., which is a small output.

The Cost of Excavation for Pavement and Curb, New York. In an article in *Engineering and Contracting*, May 16, 1906, a writer gives the following cost for excavation for asphalt pavement and a concrete curb on Broadway, from 110th to 119th St., New York City, in November, 1904.

Asphalt pavement excavation	Per cu. yd.
Foreman at $3.75	$0.026
Laborers at $1.50	0.201
Teams at $5.50	0.088
Plowing at $4.00	0.018
Carts at $4.00	0.010
For 1,985 cu. yd., cost per cu. yd.	$0.443

Excavation for curbs	Per lin. ft.
Foreman at $3.75	$0.004
Laborers at $1.50	0.020
For 2,253 lin. ft., per lin. ft.	$0.024

Teams with wagons cost $5.50, but as the contractor owned plows and carts, it was necessary to hire only teams and drivers, which reduced the daily rata per team to $4.00.

Cost of Excavation and Backfill on a Bridge Abutment. *Engineering and Contracting*, May 30, 1906, contains the detailed cost of a masonry bridge abutment on the Detroit, Lansing & Northern R. R. The cost of excavation and backfill was as follows:

Excavation

Foreman, 8.9 days at $1.75	$15.58
Laborers, 64.8 days at $1.50	97.20
Engineman, 0.4 days at $1.75	0.70
Derrickman, 0.4 days at $1.50	0.60
Total, 772 cu. yd. at $0.15	$114.08

The removal of excavated matter was done almost entirely with wheelbarrows. The material was sand and was wasted. The overhaul was short, the lead being 75 ft.

Backfill

Foreman, 2.4 days at $3.00	$6.80
Foreman, 6.3 days at $1.75	11.03
Laborers, 37.8 days at $1.50	56.70
Engineman, 3.6 days at $1.75	6.30
Derrickman, 3.6 days at $1.50	5.40
Total, 380 cu. yd. at $0.23	$86.23

Excavation for Retaining Wall. The following from *Engineering and Contracting*, May 30, 1916, relates to the construction of a retaining wall at the round house of the Detroit, Lansing and Northern R. R., at Grand Rapids, Mich. The contractor furnished the labor only. The excavation was nearly all stiff clay with stone and small boulders, making hard digging. Almost all of the excavated matter was handled twice, cast out on the ground and then loaded on flat cars. The time given for excavation includes $6 or $8 worth of time spent in moving cars. In all of the work the contractor was considered as a foreman and was allowed 40 ct. per hr. for the time he himself actually worked. In all of the cases the foremen hours are for the hours during which actual work was done by them; that is to say, the foreman not only acted as overseer, but also did actual work, excavating, laying stone, etc.

The cost of the excavation work was as follows:

Foreman, 33 hr., at 40 ct.	$13.20
Foreman, 104 hr., at 22½ ct.	23.40
Laborer, 285 hr., at 12½ ct.	35.63
Total	$72.23

A total of 168 cu. yd. was excavated at a cost of $0.43 per yd. The contract price at which the work was let was $.0.25.

In backfilling, the earth was wheeled from the flat cars and placed back of the wall. A small amount of earth was cast in directly from the bank. The cost of this work was as follows:

Foreman, 4 hr. at 40 ct.	$1.60
Foreman, 11 hr. at 22½ ct.	2.48
Laborer, 52 hr. at 12½ ct.	6.50
Total	$10.58

The back filling amounted to 63 cu. yd., and this was done at a cost of $0.17 per cu. yd. The contract price was $0.25 per cu. yd.

Cost of Excavation for a Railway Culvert. This job, as described in *Engineering and Contracting*, Aug. 12, 1908, was done on some railroad construction in Tennessee. The culvert was a 4 x 4 box culvert of rubble masonry, 42 ft. long. The excavation was 12 ft. wide and 2½ ft. deep. The material excavated was a dry sandy clay that was easily worked, although it had to be picked before it could be shoveled. When material in culvert excavation can be spaded, thus saving the picking, the work can be done much cheaper.

The excavated material in this case was shoveled on to the ground on each side of the culvert, the ends being left open. At each end of the culvert a ditch 4 ft. wide was c t to the culvert excavation, making 53 cu. yd. of excavation for the culvert and ditches. This earth piled up on the two sides of the pit would make about 65 cu. yd. loose measurement, making it necessary to handle some of the material a second time. This fact and likewise the width of the pit, 12 ft., necessitated casting the earth some distance, thus adding to the cost of the work. At least half the material was handled a second time, and about 10% was handled three times.

The cost of the work was as follows per cu. yd.:

Foreman at 25 ct. per hr.	$0.14
Laborers at 12.5 ct. per hr.	0.59
Water boy at 5 ct. per hr.	0.03
Total	$0.76

A man excavated, that is picked and shoveled, about 2 cu. yd. per day, of the original excavation, or about 3½ c . yd. per day including the material that was handled more than once.

This is a very high cost for this work. One reason for this high cost was a very inefficient foreman. He was discharged.

Another reason was that the contractor did not furnish long handled shovels to the men. To cast the earth 10 ft. or more with short handled shovels was much more expensive than if long handled shovels had been used.

In *Engineering and Contracting*, Aug. 5, 1908, the following cost of excavating for a culvert is given. This culvert was a 3 x 4 box masonry culvert, the excavation being 40 ft. long and 9 ft. wide, and averaged 1 ft. in depth. The material was sandy gravel and stiff clay. The stream was a small one and was easily diverted to one side, but, owing to the top soil being sandy gravel, the water percolated into the foundation as fast as it was dug. However, it was not necessary to pump it out, as a small trench cut at the lower end of the foundation pit carried off the water, care being taken in carrying on the excavation to do it so that the pit drained itself by means of this trench. However, this water made the clay wet and heavy and much more expensive to handle.

The crew that did the work consisted of a foreman and 4 men, who finished the job in one day. There were 13 cu. yd. of material excavated, at the following cost per cu. yd.:

Foreman, at 25 ct. per hr.	$0.19
Laborers, at 15 ct. per hr.	0.45
Total	$0.64

This shows how large a proportion of the cost the foreman charge can be, where the gang is necessarily small. In this case supervision was nearly 33% of the total cost. Each workman in 10 hr. excavated 3½ cu. yd. This meant that he loosened and shoveled it. With the material dry and in a bank it would have been possible for a man to have done at least 10 to 12 cu. yd. in a day, thus showing that prices paid for ordinary excavation would not cover the cost of this wet excavation.

Labor Cost of Excavating in Stiff White Clay. *Engineering and Contracting*, May 15, 1918, gives the following:

The following labor costs cover the excavation in stiff, white clay for a sewage disposal plant. The excavation was 19½ ft. long by 14 ft. wide, 7 ft. deep and contained 71 cu. yd. The work was done during good weather, but by a poor foreman and average crew. Some water seeped in the bottom foot, delaying the work somewhat.

The costs follow:

	Per cu. yd.
Foreman, 40 hr. at 40 ct.	$0.225
Labor (excav.), 246 hr. at 35 ct.	1.210
Labor (timbering), 16 hr. at 35 ct.	.079
Total (71 cu. yd.)	$1.314

The above costs cover excavation only. Hauling away surplus earth is not included. The backfill (16 cu. yd.) cost 28 ct. per cu. yd.

Handling Soft Material. On ditching work in light marshy soil where tough sod and numerous small roots are to be contended with, a hay knife will be found useful. This should be pushed as deep as possible along each side of the ditch, cutting the roots so that each spadeful has one side free. Other data on the subject of handling soft material will be found in the chapter on ditches.

Excavating Swamps in Freezing Weather. In the *Journal of New England Water Works Association*, Vol. 15 (1900), Mr. John L. Howard gives a description of a method of excavating a swamp. A Hayward grapple excavator loaded the muck into the hopper from which it was distributed into cars holding about 1 cu. yd. each. These cars were hauled in trains of six by a hoisting engine to the top of the dump along which they were switched to the place of disposal. The muck was so completely saturated with water that the dump became a quagmire. A platform was built under the track to keep it from sinking, but after every shower more planks and considerable labor were required to keep it in alignment, and even then the cars would not stay on.

The difficulty was solved by waiting until cold weather set in. The surface of the ground became frozen and carts could be used without any difficulty. A pump sump was kept well down ahead of the excavator.

Cost of Plowing. A plow or a pick is ordinarily used for loosening, the plow being the most economic under ordinary conditions.

Whenever the word "team" is used I mean two horses and their driver; if I refer only to the horses, I shall say a horse or a pair of horses.

A two-horse team with a driver and a man holding the plow will loosen 25 cu. yd. of fairly tough clay, or 35 cu. yd. of gravel and loam per hr. In the far West some contractors always use a four-horse plow even in light soils, but when very tough clay or hardpan is encountered a pick-pointed plow with four to six horses, and two extra men riding the plow beam will always be required, and will loosen 15 to 20 cu. yd. per hr. In such soil a steam roller or a tractor is very effective, and more economic than horses as a plow puller.

One example to show the high cost of plowing the hard crust of an old road will suffice: An old village street, partially graveled, was plowed up 9 ft. wide × 1,400 ft. long × 14 in. deep

(= 550 cu. yd.) by one plow team with driver and a man holding plow, in 2¼ days, or 244 cu. yd. per day, at a cost of 2 ct. per cu. yd. Another similar but harder stretch was plowed with two teams on the plow and a man riding the plow beam, at a cost of 6 ct. per cu. yd. While the average cost of plowing 5,500 cu. yd. of such compacted gravel and earth roadway was 4 ct. per cu. yd. for plowing alone, wages of men being 15 ct. an hour and team with driver 35 ct. an hour. Contractors having old streets or roads to loosen will do well to keep in mind these figures.

Morris found that a team, a driver, and a plowman would loosen:

20 to 30 cu. yd. per hr. of "strong, heavy soil."

40 to 60 cu. yd. per hr. of "ordinary loam."

Specht states that a six-horse plow with one driver and one plow holder would loosen 1,000 cu. yd. of sand, and 700 cu. yd. of sandy loam per day, ready for the buck scrapers to remove.

Earthwork Plows are of rugged construction as their chief use is in very hard ground. A plow made by the Baker Mfg. Co. is shown in Fig. 14. It is made in the following weights and sizes:

	No. horses	Beam	Weight
No. 0	2	6 ft.	180 lb.
No. 1	2 to 4	6½ ft.	200 lb.
No. 2	4 to 6	7½ ft.	270 lb.
No. 3	6 to 8	8½ ft.	350 lb.

All sizes cut a 12-in. furrow.

Fig. 14. Railroad and Township Grading Plow.

A plow weighing only 150 lb., and said to be light enough for two horses and at the same time strong enough to resist the pull of ten horses is shown in Fig. 15.

In tearing up hardpan, frozen ground, macadam, etc., a special type of plow called a rooter is used. It does not turn over the soil as does the ordinary plow but merely loosens it. A rooter plow which complete weighs 275 lb. is shown in Fig. 16. It can be used with either horses or a traction engine.

Fig. 15. Light Grading Plow.

Fig. 16. Steel Beam Rooter Plow.

The following table gives the cost of plowing when wages of laborers are $1.80, and of teams (2 horses and driver) $5.40 per day of 9 hr.

COST OF PLOWING

Soil	Labor	Cu. yd. per hr.	Per cu. yd.
Loam	1 driver, 1 holder, 2 horses	50	$0.014
Gravel and loam	1 " 1 " 2 "	35	0.023
Fairly tough clay	1 " 1 " 2 "	25	0.032
Very hard soil...	1 " 1 " 4–6 " 2 men on plow beam of rooter plow	15–20	0.08
Ordinary soil	1 driver, 6 horses on gang plow	40	0.035

Gang Rooter Plow. Fig. 17 shows the improved model of the Petrolithic gang road rooter plow (made by W. A. Gillette, South Pasadena, Calif.). It consists of a steel frame with two wheels in front and the same number in the rear. The wheels are controlled by levers so they can be raised or lowered from the ground. In this manner the exact depth to which the rooters or plows penetrate can be regulated. If it is desired to loosen a crust only 2 in. deep, it can be done; if it is desired to plow

to the depth of 12 in., this is also possible. The five rooters or plows are so fastened in the frame that any one or all can be removed if desired, and each rooter is provided with a removable point, which can be taken off and sharpened without removing the entire rooter from the frame.

Only one man is required for operating a steam roller, which serves as a traction engine, and the gang rooter. At the end of a run, this engineman simply raises the rooters out of the ground by means of a lever, turns around, sets the levers again and goes back. *Engineering and Contracting*, Nov. 10, 1909, states that this gang rooter, and a road roller or traction engine, has actually broken more ground in one day than 12 horses hitched to an ordinary rooter plow had previously broken in 6 days.

Fig. 17. Petrolithic Gang Road Rooter Plow.

Mr. W. A. Gillette, in *Engineering and Contracting*, June 28, 1911, gives the cost of plowing an old street with one of these Petrolithic gang rooters. The machine was drawn by a 12-ton gasoline road roller. One man operated the rooter, which was easily set so as to break ground at any depth from 6 to 15 in. in a strip 5 ft. wide. The gasoline roller developed sufficient power to pull the rooter in an old and very hard asphaltic oiled road. It lost very little time for stops and used a minimum of fuel, no stops were made during working hours to take on fuel. A usual day's work was nine hours. The operating cost of the roller was as follows:

	Per day
35 to 40 gal. distillate @ 8 ct. per gal.	\$3.20
0.75 gal. lubricating oil @ 45 ct. per gal.	0.34
Engineman	4.00
Total	\$7.54

Dynamometer Tests on Plows. *Engineering News*, Aug. 17, 1911, published the results of some tests made by Wm. Clyde Willard.

In making the tests a "Pattern B" Schaeffer & Budenberg recording dynamometer registering to 4,000 lb. was used. In this instrument the paper record slip was fastened on a drum 4 in. in diameter making one revolution per hr.

The results in pounds were obtained by planimetric averaging from the record slips. The area enclosed by the dynamometer autograph, the zero line and the ordinate at beginning and end of run, was measured by a rolling planimeter. This area was divided by the length of the zero line to give average pull. Some difficulty was encountered owing to the fact that the clockwork which revolved the drum of the dynamometer ran so slowly that the lines made by the pencil overlapped each other to such an extent that it was impossible to trace out each separate line. To overcome this the lines joining the points of maximum and minimum pull were traced by the planimeter and the mean of the two areas taken as the result. This probably gave as accurate a result as could have been obtained had it been possible to trace each pencil line throughout its entire length.

In conjunction with the tests on wagons several tests were made to determine the tractive resistance of plows. The results should be of great interest to all users of plows or to those interested in farm mechanics. Two plows of different manufacture were used. Test group A (Table I) was made with a Parlin & Orendorf 14½-in. two-bottom gang plow; test group B (Table II) was made with an Oliver chilled 14½-in. two-bottom gang plow. Each plow was drawn by six horses. The results are tabulated below.

TABLE I.—TRACTIVE RESISTANCE OF PLOW IN STUBBLE LAND

Test number	Description	Draft in lb.
1	7-in. cut, loose stubble land on about a 10% grade, man rode	900
2	Same as 1, except that man walked	883
3	All conditions the same as 1, except that the coulter was moved ½-in. toward the land side of the furrow and several bolts about the plow were tightened	776
4	Same as 3, except man walked. (The increase in draft was caused by the plow not scouring for a part of the distance.)	822
5	7½-in. cut, otherwise the same as 4	849

TABLE II.—TRACTIVE RESISTANCE PLOW IN CLOVER SOD

Test number	Description	Draft in lb.
6	6½-in. cut, heavy clover sod, almost level	949
7	6½-in. cut, thin clover sod, coulter ½-in. in furrow, furrow wheel ran free	850
8	Same cut and sod as 7, coulter ¼-in. outside of furrow, furrow wheel ¼-in. below land side	689
9	Same sod and cut as 7 and 8, coulter same as 8, furrow wheel ¾-in. below land side	697

In the tests reported in Table I, a change of ½ in. in the position of the coulter made a difference in draft of 124 lb., or a difference of almost one horse. Tests 1, 6 and 7 show the difference in resistance of the two sods and stubble. Tests 7, 8 and 9 show the change in draft made by a shift in the positions of the furrow wheel and coulter. Comparing 7 and 8 it is seen that shifting the position of the coulter ¾-in. and lowering the furrow wheel ¼-in. made a difference in draft of 161 lb., or over one horse difference. Five horses could have pulled the plow easier after the shift than the six could before. The resistance is increased by having the furrow wheel too low, as shown in Test 9.

Cost of Plowing with a Steam Traction Engine. *Engineering and Contracting*, June 16, 1909, gives the following:

It is only within the last ten years or so that the feasibility of plowing with traction engines has become generally recognized. The results obtained have been very satisfactory, and when it is remembered that one man with a plowing outfit can do much more work than six or eight with horses, the advantages of this method on the large farms of the West are obvious. Some data on the cost of steam plowing taken from letters written to the manufacturers by users of the traction engine are given below.

The first piece of work for which data are given was done in Missouri last year, a 20 hp. Rumley Standard traction engine and an 8-gang 14-in. Moline steam plow being used. An average of 18 acres per day was plowed, the cost of operating per day being as follows:

	Total	Per acre
Engineman	$ 3.00	$0.166
Water and fuel, hauled with team	2.50	.139
Plowman	1.00	.055
Coal	3.00	.166
Plow sharpening, oil, etc.	.50	.027
Total	$10.00	$0.553

The next piece of work was done in North Dakota, a 30 hp. Rumley engine and Emerson 16-in. plow being used. The cost was as follows:

	Per acre
Coal, at $6 per ton, 90 lb. per acre	$0.27
Cylinder oil, at 40 ct. per gallon	.01¼
Machine oil, at 20 ct. per gallon	.01
Fireman, $2.50 per day	.06¼
Water, team and man for hauling, $4 per day	.10
Sharpening lays	.01
Gear grease, 4 ct. per lb.	.00½
Total	$0.47

It will be noted that there is no allowance made for engineman in the above, the owner of the outfit probably acting as such. Charging this item up at $4.00 per day would bring the cost per acre to 57 ct. The fireman also probably acted as plowman. The outfit traveled 2¼ miles per hr., cutting 16½ ft., thus averaging four acres per hr., allowing for stops. The last piece of work was also done in North Dakota, a 30-hp. Rumley plowing engine being used. The ground was stony and hilly and a disc plow with 14 discs and cutting 11 ft. wide was used for breaking the ground. An average of 16 acres of ground was broken per 12-hr. day, the cost being as follows:

	Total	Per acre
Coal, 2,300 lb., at $7.50 per ton	$ 8.05	$ .50
Water, team and man for hauling	4.50	.28
Engineer	3.00	.11
Plowman (who also fired)	2.00	.12
Oil and incidentals	1.00	.06
Total	$18.55	$1.07

Later on this ground was put in shape for the drill at a cost of about 50 to 60 ct. per acre. To do this the traction engine was used to three sections of 21 discs cutting 18 ft. wide with a large drag and float behind.

Tractor Plowing. Mr. J. Gardner Bennett in *Engineering News*, Mar. 11, 1915, describes the use of a small gasoline tractor for breaking soft muck land on a Southern reclamation project. This machine was driven by a 20-hp. 4-cylinder motor, and was equipped with three small "caterpillar" wheels which gave a bearing surface of 2,800 sq. in. for a total weight of 4 tons. The price of the machine was $2,500. The cost of breaking soft muck land was about as follows: Operator's wages for a 10-hr. day, $3; gasoline, $2; lubrication, $0.40. This gives a total operating cost of $5.40 for plowing five acres, or $1.08 per acre.

Traction Plowing Outfits. Bulletin 170, U. S. Department of Agriculture, gives a large amount of data on plowing with traction outfits, as well as on the cost of operating steam and gasoline tractors under average farm conditions. Plowing costs are given as follows:

COST OF STEAM PLOWING
(Including Harrowing)

	Cost per acre
California	$0.853
Southwest	1.14
Northwest	1.73
Canada	1.898

The cost of plowing, including some harrowing, with gasoline engines is given as $1.409 per acre. The depth of plowing is not stated but it is safe to assume it as fully 6 in. An acre 6 in. deep contains approximately 800 cu. yd. Thus if farm conditions can be approximated on an excavation job, it will be possible to loosen earth with traction-drawn plows at a cost of from 0.1 to 0.3 ct. per cu. yd.

Loosening with Explosives. Some earthy materials are more economically loosened by explosives than by either picks or plows. Even where the material to be excavated is soft enough to plow, "the lay" of the land or the method of excavating may make plowing impossible. Explosives are the most economical means of loosening for drag line scraper and steam shovel work. In addition to loosening, explosives if used in sufficient quantities, will throw the earth considerable distances; as in making holes for tree planting or in digging ditches.

In the "Engineer Field Manual, Professional Papers, No. 29, Corps of Engineers, U. S. Army," data are given as to the amount of explosive required to make military mines, from which the following brief tables are taken. The values given are to be regarded as approximations only. The maximum loosening effect is obtained from the explosions of the powder when no earth is displaced on the surface. A sphere of earth is ruptured about the charge as a center. In military parlance this type of mine is called a "camouflet." Where the radius of rupture is to be equal to the depth at which the charge is placed, multiply the cube of the depth in feet by the following factors to obtain the required number of lb. of 50% dynamite.

Light earth	0.005
Common earth	0.006
Hard sand	0.007
Hardpan	0.008

These factors apply to only one type of mine. According to them 1 lb. of dynamite placed 6 ft. below the surface in light earth and properly tamped will rupture about 33 cu. yd. of earth. The amount of earth ruptured varies directly as the amount of powder used, but only if the conditions above set forth are fulfilled. Thus 2 lb. of dynamite placed 6 ft. below the sur-

face will not rupture 66 cu. yd. because the surface will be broken and much of the force of the explosion lost. Placed 7.5 ft. below the surface the two pounds would rupture about 66 cu. yd.

It is often desirable not to loosen the subgrade, in which case such blasting charges can only be placed at half the depth of excavation. Under these conditions it may be desirable to use larger quantities of explosives than above indicated, in spite of the fact that part of their force is expended in making a crater. In this case the relief of pressure in one side shortens all radii of rupture which have a component in that direction, and the volume of rupture is ellipsoidal. For a "Common Mine," diameter approximately equal to twice the depth of charge, having its greatest horizontal radius of rupture equal to 1.7 times depth of charge and vertical (downward) radius of rupture equal to 1.1 times the depth of charge, the following factors are given:

Light earth	0.012
Common earth	0.015
Hard sand	0.042
Hardpan	0.050

Figuring from the above data a charge of approximately 2½ lb. of 50% dynamite placed 6 ft. down in light earth will loosen about 48 cu. yd. of material. Here an increase of 250% in dynamite over the requirements of the "camouflet" produces less than a 50% increase in the amount of dirt loosened. While these figures are rough approximations they serve to show the folly of using excessive amounts of explosives in loosening earth.

Consult Gillette's "Handbook of Rock Excavation," for further information on blasting.

Cost of Blasting Hardpan. (From *Engineering and Contracting*, Aug. 19, 1908.) In all about 80 holes were drilled, each hole being put down to a depth of 6½ ft., making 520 ft. of drilling necessary. These holes were put down by two men with a 12-ft. churn drill, taking about 8 days to do the work. This meant 10 holes drilled per day, or about 65 ft., and, with wages at $1.25 for 10 hr., gave a cost for drilling of about 4 ct. per ft. It took about two days' time for these two men to dry the holes (water stood in the bottom of them) and do all the necessary blasting, thus costing about 6 ct. per hole for labor for blasting, making all the labor of drilling and blasting 4.4 ct. per ft. of hole.

About 2 lb. of 40% dynamite was used to the hole, 172 lb. being actually used for all the holes. This meant an average of 0.28 lb. of dynamite per cu. yd. of cemented gravel. The total cost of blasting was:

Laborers, 20 days, at $1.25	$25.00
172 lb. dynamite, at 11½ ct.	19.48
80 electrical exploders, at 4 ct.	3.20
Total	$47.68

For the 600 cu. yd. of cemented gravel this is a cost of 8 ct. per cu. yd. for blasting, but if we distribute this cost for the 1,000 cu. yd. of excavation, the cost becomes 4¾ ct. per. cu. yd.

This work was done in making a channel 20 ft. wide on top and 15 ft. wide on the bottom, 6 ft. deep and 250 ft. long. The top 2½ ft. was sandy clay while the rest of the material was a hard cemented gravel.

Breaking Up Hard Ground with Dynamite is described in *Engineering and Contracting*, Nov. 13, 1912, as follows: Although road contractors have commonly used dynamite for blasting rocky cuts in road work, the use of high explosives for moving gravel, clay or old road beds is a recent innovation. At a demonstration given recently by the Du Pont Powder Co. to the Park Department of Los Angeles to show the value of dynamite blasting in hard ground, 30 holes were bored to a depth of 6 ft. (to grade), spaced 4 ft. apart and each loaded with two cartridges. As a result of the blast the dirt was loosened to grade, making further plowing unnecessary. The ground was so hard that they had been using six mules to a plow and at each plowing were loosening only about 8 in. of dirt. Low grade dynamites are best for this work, as they have the slow, heaving effect that is most advantageous in dirt work.

Breaking High Banks. In excavating a high bank of hardpan, 12 to 15 ft. high, an economical method is to churn a hole some 8 to 10 ft. deep, and about 8 to 12 ft. back from the bank and to load this with a small charge of black powder. Sufficient powder is used to crack the bank, but not to throw very much of it down. Thus the earth is easily undermined or barred down, as the case may require, breaking into small pieces by reason of its fall.

Excavating Holes with Explosives. The following is taken from *Engineering and Contracting*, Apr. 15, 1908. A hole was churned in the ground where the tree was to be planted, with a churn drill, at an angle with the surface of 35° to 40°. The hole was made about 2 ft. deep, and loaded with a half stick of 40% dynamite (¼ lb.) and shot. This blew out of the ground a hole about 3 ft. in diameter and about 2 ft. deep, making a hole the shape of a cone. The soil left in the bottom of the hole was well pulverized, admitting of the tree being planted without further preparation.

One man accustomed to handling explosives, with a helper, blew out on an average 250 holes per day, working 10 hr. The

dynamiter prepared the charges and loaded the holes, tamping them but little, while the helper churned the holes and assisted in other work.

The cost of blowing 250 holes was:

1 man	$ 3.50
1 man	1.50
500 ft. fuse at 45 ct. per 100 ft.	2.25
250 caps at 75 ct. per 100	1.87
63 lb. of dynamite at 15 ct.	9.45
Total	$18.57

This gives a cost of 7.4 ct. per hole. From each hole about 4.7 cu. ft. of earth was excavated, being equal to .17 cu. yd. At the above cost this makes 43 ct. per cu. yd. In such a hole trees as large as 4 in. can usually be planted.

With a deeper hole and a larger charge of explosive larger holes could no doubt be blown out. It would also be possible to use either black powder or Judson instead of dynamite, and the work might be cheapened by the use of either of them.

See Gillette's "Handbook of Cost Data" for further information on hole digging and tree planting.

Blasting a Pit for a Dredge. In order to float a dipper dredge for the purpose of digging a ditch at Madrid Co., Mo., according to *Engineering News*, June 24, 1915, it was necessary to excavate a pit 136 x 50 x 6 ft. in size. Eleven rows of holes, 3 ft. apart, were driven. The holes in the center row were loaded with 2.5 lb. of dynamite each, those in the next two rows on each side 2 lb. each, in the next rows with 1.5 lb. each, in the next with 1 lb. each and in the outside rows with 0.5 lb. each. The holes in the outside rows were 18 in. apart, in the next rows, 2 ft. apart, in the next 2.5 ft. apart, and in the rows alongside the middle row, 15 in. apart. A total of 950 lb. of dynamite was used.

The blast resulted in a hole 136 x 43 ft. in area, 7 ft. deep at the center, and an average of 3.5 ft. deep. In all, 747 cu. yd. were removed at an expenditure of about 1.3 lb. per cu. yd.

Eliminating a Mosquito Breeding Pool by Blasting. The following item was extracted from the Year Book for 1916 of the Commissioners of the Borough of Haddonfield, N. J. (*Engineering and Contracting,* Aug. 9, 1916.)

"The residents of West Haddonfield were for years pestered and tormented by mosquitoes which it was learned, upon investigation, were propagated in stagnant pools between the railroad and Haddon Ave. It was found practically impossible to drain these to the street gutters, hence another method had to be employed and it was decided to sink the water into the ground. Under the supervision of L. Z. Lawrence a heavy charge of dy-

namite was sunk and discharged about 20 ft. under the surface. This caused the pools to disappear in short order and no water has accumulated at this point up to the end of the year."

Dynamiting a Dredgeway. Paul R. Higgings, in *Engineering and Contracting*, Aug. 16, 1916, is author of the following:

A small creek ran under a concrete bridge 22 ft. in width. It was desired to run dredges under the bridge, but the creek was not deep enough, nor wide enough. I was given the contract at a price of 80 ct. per cu. yd. to deepen and widen the creek for 60 ft. on either side of the bridge.

I began operations directly under the bridge. It was impracticable to load heavy charges at that point, so I put down a row of bore holes 2 ft. back from the bank of the stream, spacing them 2 ft. apart and making them 2 ft. deep. Each hole was loaded with a half stick of 60% dynamite. I worked in this way from both ends toward the middle. It was necessary for me to make use of these little shots at the 2-ft. distances all the way down these lines in order to get the required excavation.

This method of blasting resulted in throwing most of the dirt into the creek bed, which was at that time dry. Two hours' work with team and scraper at a cost of 50 ct. per hr. were required to remove the dirt.

After finishing under the bridge, the work was much easier, as I could load more heavily. Parallel rows of holes were put down on each side of the creek 2 ft. back from the banks, 6 ft. deep and 4 ft. apart, each hole loaded with from seven to nine

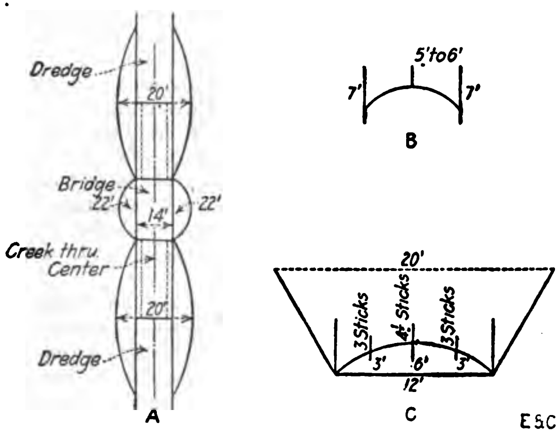


Fig. 18. Method of Enlarging a Creek Bed by Dynamite.

sticks of the 60% dynamite. An electric cap was used in each charge and the charges were fired electrically. Fig. 18, A1, will illustrate this operation. These side blasts threw most of the dirt over into the dry creek bottom, leaving the work in the condition indicated by diagram B, Fig. 18.

I then put down a single row of holes directly down the center of the hump, also two more parallel rows of holes on either side of the center line. These side lines were each about 3 ft. from the center line. The center line of holes was about 6 ft. deep; the side lines from 3 to 4 ft. My center line of holes (all the holes were from 2 to 3 ft. apart) was loaded with about 4½ cartridges each of the straight dynamite, and the side line of holes with about three cartridges each.

This final shot resulted in throwing the dirt out on the banks, leaving a nice clear ditch nearly 20 ft. wide at the top and about 12 ft. wide at the bottom. Diagram C, Fig. 18 will illustrate the loading for this last shot and the approximate shape of the ditch after the blast.

Digging Ditches with Dynamite. Arthur E. Morgan in *Engineering and Contracting*, Feb. 1, 1911, is author of the following:

In the lowlands of southeast Missouri, a considerable amount of excavation for drainage ditches is now being made with dynamite, a method of construction discovered by accident in 1909. In blowing large stumps preparatory to digging drainage ditches, it was noticed that where several stumps close together in a line were blown out, a depression remained which had approximately the dimensions of the required ditch. Acting on the suggestion thus offered, efforts were made to blow out a channel by placing a single charge at a time, with results which were not satisfactory. Next charges were placed in the ground 2 ft. apart for a distance of 100 or 200 ft., and an effort was made to discharge them at about the same time by means of fuses. As the explosion of all charges was practically instantaneous, it was apparent that all but the first had been discharged by concussion.

The experimenters continued setting charges 2 or 3 ft. apart for distances up to a quarter of a mile, and found in all cases that it was necessary to set a fuse to only one of the charges, in order for the whole to be exploded. Up to the present this method is in use only for the construction of small ditches 3 or 4 ft. deep and 6 to 12 ft. wide.

The dirt removed by the dynamite is thrown onto both sides for 100 ft. or more, and does not lie more than 6 in. or 1 ft. deep along the margins of the ditch. The charges are set by making a hole of the necessary depth with a bar, and then push-

ing the dynamite into the hole with a wooden stick, tamping dirt on top. In order to secure a uniform cross section it is found necessary to place the charges at equal distances apart, and at such a depth that they will be on the proposed bottom line of the ditch, and that the charges should be approximately equal in size.

The best of the channels constructed in this manner are as nearly uniform in cross section as they could be made by using teams and scrapers.

One of the ditches examined, which had been constructed about a year, was 6 ft. wide on the bottom, 12 ft. wide on top, 3½ ft. deep, and in good order. In digging it two ½-lb. sticks of 50% dynamite were placed 3 ft. apart in the ground and between 3 and 4 ft. deep. Two men will construct a quarter of a mile of ditch in a day.

At a cost of 15 ct. per lb. for dynamite, and $20 per mile for placing the charges, the ditch in the condition in which it was examined, after a year of depreciation, had cost about 5 ct. per cu. yd. The ditch had been constructed through the woods without cutting down any of the trees, and in some instances the fallen trunks were lying across the channel.

This method of construction is coming into general use in excavating lateral ditches in the wet muck soils of southeast Missouri. Its advantages lie in its usefulness for digging ditches too small for a dredge, and through ground too wet for economical work by hand or with teams and scrapers. Whether larger channels can be constructed by using larger charges of dynamite, placed at greater depths, remains to be seen.

Sandy soils are not handled as readily as clay or muck, and where ditches have been blown out in sand, the cost per yd. has been several times as great. Neither does the method work well in dry soil. The use of 60% dynamite has in some cases given better results than 50%. If the success achieved by this method of excavation is repeated in other parts of the country, it will appear that we have added to our construction methods another means of earth excavation, applicable to wet muck and clay soils, under conditions where none of our former methods of excavation were economical for the construction of small channels.

Ditching and Digging Pole Holes wih Dynamite. From an article by Thomas M. Knight in *Engineering and Contracting*, July 19, 1916.

There are hundreds of thousands of miles of ditches needed in this country. Excess water must be carried away, and in the arid regions water must be brought to the land. Ditches both small and large, deep and shallow, to fill the particular

needs are required. How to dig these ditches at the least cost in the quickest time possible is a question of vital interest to the engineer.

In times past, pick and shovel, mechanical diggers, heavy ditching machinery and floating dredges all played their part in the excavation of ditches. In recent years dynamite has been added to this list. All of these methods have their place; yet for a great many classes of ditches the use of dynamite is cheapest and most satisfactory. However, in cases of ditches of from one to several miles in length and 6 ft. deep or over other means than by the use of dynamite will probably be found more economical, but for ditches from 3 ft. wide to 2 ft. deep up to 16 ft. wide and 6 ft. deep the use of dynamite will be found to be a very economical way of digging. Ditches may be dug with dynamite in the softest swamp lands or through the hardest rock. In fact, dynamite will do the work in any soil, with the exception of loose, dry sand.

In ditching with dynamite no expensive machinery is required, and the cost and labor of transporting this machinery is eliminated. The equipment required is generally a sledge and punch bar or soil auger, and very often two men can carry all the supplies that are needed for a few hundred feet of ditch. Dynamite works exceptionally well in rough and swampy lands, and will dig a clean-cut channel through places so wild that teams or machinery could not be brought to work in them. A little shoveling is sometimes required, and, as the blast scatters the soil over an area approximately 150 ft. on each side of the ditch, there are no spoil banks with which to contend in aftertimes. It is as easy to dig a curved ditch as a straight one, as the center of the ditch is where the dynamite cartridges are placed.

In wet weather it is often imperative that a ditch be dug very quickly to avert the flooding of certain sections, and the use of dynamite in cases like this is the means of saving an untold number of dollars.

There are two methods of blasting ditches, propagated and electric. The propagated method can be carried on only in wet soils, while the electric one may be practiced in both wet and dry soils. The grades of explosives used, blasting supplies needed, and methods of loading vary with the two methods.

In wet or swampy soils the ditching can best be done by the propagated method. In firing a propagated blast the cartridges are placed from 18 to 24 in. apart and at the proper determined depth. A blasting cap with fuse is inserted in the center cartridge and fired. The force of the explosion of this

cartridge fires or detonates the balance of the cartridges so placed. If the ditch is to be a wide one, then a parallel row of cartridges, and sometimes a third row, is required. In such a case there should be an extra cartridge or two put down to connect the parallel rows to make sure of the simultaneous detonation of all the charges. It is also good practice to charge the two cartridges on each side of the primer with a blasting cap, to further insure perfect detonation. In a propagated blast a straight nitroglycerine dynamite must be used, as other grades are too insensitive to be fired in this manner. This method of blasting should be carried on only in a fairly warm soil. It should not be attempted in icy water or in cold weather.

If stumps, boulders, or other obstructions are directly in the line of the ditch it is best to prime a cartridge on each side of the obstruction and fire these with an electric blasting machine. The explosive wave might carry through or around these, but it does not pay to take the risk. When such obstructions are to be removed from the ditch, extra charges should be placed under them.

The electric method of blasting ditches may be carried on regardless of soil conditions and temperature. It has the advantage over the propagated method in that the low freezing and less sensitive grades of dynamite may be used and larger charges may be employed in the hole, and these placed correspondingly farther apart, thus reducing the cost. The method of procedure is exactly the same as with the propagated blast, except every charge must be primed with an electric blasting cap, and the wires connected up. To fire this an electric blasting machine is used. Where more than one cartridge is used in a hole, the one containing the primer should be placed on top and the cap pointed downward. Blasting machines have limited capacities; so don't overload them. If one is rated at fifty, it is far better to fire forty-five charges than to try to fire fifty-five. Be on the safe side. Where the water does not rise 2 ft. in the hole, it should be filled with suitable tamping material and packed tightly.

If one set of holes is to be fired they can best be connected as shown in Fig. 19. Fig. 20 also shows a method of connecting one line of holes. For two sets of holes the connections are made as in Fig. 21. If a ditch is of a sufficient width to demand three lines of holes, the method of connecting the wires is shown in Fig. 22. Fig. 23 gives a view of the longitudinal section of the placing of charges and wiring for an electric ditch blast.

The amount of dynamite needed, the space between the charges,

Fig. 19. Plan of Wire Connections for Blasting a Narrow Ditch Through Dry Ground.

Fig. 20. A Second Method of Wiring One Line of Holes.

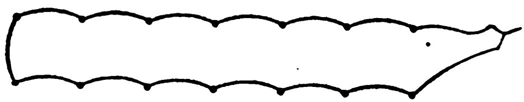


Fig. 21. Plan Showing Method of Connecting Wires for Blasting a Large Ditch Through Dry Ground.

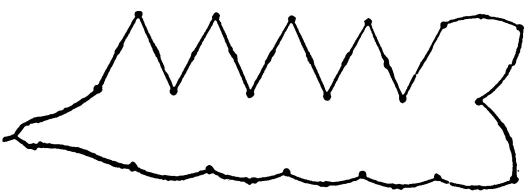


Fig. 22. Method of Connecting Wires for a Ditch Blast Where Three Lines of Holes are Used.

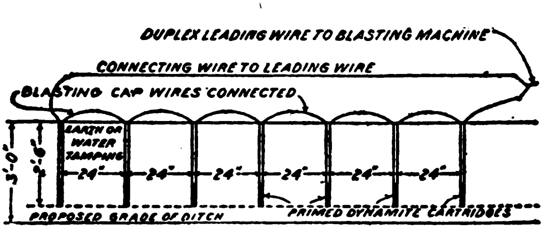


Fig. 23. Longitudinal Section Showing Method of Loading With Electric Blasting Caps for Blasting a Ditch.

and the depth to which they are placed to dig a ditch of the required size vary greatly. No set rule can be laid down. Roughly speaking, in average soils a pound of 50% straight nitroglycerine dynamite should dig a running yard of ditch 6 ft. wide and from 2½ to 3 ft. deep. That would mean the placing of a cartridge of dynamite every 18 in. at a depth of about 30 in.

The only sure way to proceed either in a propagated or electric blast is first to fire trial or test shots. For ditches from 3 to 3½ ft. deep the depth of the bore or loading holes should be from 2 to 2½ ft. and the spacings from 20 to 24 in. apart. It is well to load about ten holes as a trial and note the results. If a clean ditch has been blown to the required width and depth, the work may proceed, but if too deep or too shallow, vary the spacing, depth, and charges accordingly. Two or three test shots in most cases will determine the correct loading. In some cases where a shallow ditch is required and the soil is soft and wet, half a cartridge will be sufficient to do the work. When the dynamite moves too much ground in propagated blasts and the spacing

Fig. 24. Dynamite Charges Tied to a Stick and Ready to Load for a Post Hole Blast.

between the charges is 24 in., cut down the size of the charge rather than increase the spacings, as 24 in. is usually the limit of successful propagated blasts.

The holes can be put down in swampy and wet land with a wooden stick or bar with little trouble, while in harder soils a hole may be put down with a bar and sledge or crowbar.

Soil conditions vary in every location; so it is impossible to arrive at any cost prices until test shots have been made. Table I gives the approximate amount of 50% straight nitroglycerine dynamite required to dig ditches of various width. Table II shows the amount of dynamite required for a given length of ditch.

Dynamite is also employed to good advantage in digging post and pole holes.

In digging pole holes with dynamite the dirt is packed solidly around the sides of the hole, which is greatly to be desired. The tendency in hand digging in hard soils or shale is to make the holes shallow. This danger is wholly eliminated where explosives are employed.

In preparing to blast out a hole with dynamite, a hole is first

dug with a spade about 6 or 8 in. deep to the full diameter of the hole required. This is to relieve the pressure on the blasted hole and to prevent excessive shattering.

A bore hole is then put down in the center of the shallow hole to within about 6 in. of the depth required. A soil auger or churn drill will probably work the best in putting down this hole.

The dynamite used in blowing out the hole must be divided into several charges and spaced so that when placed in the hole the top charge will be about 20 in. below the surface. The charges, consisting of a cartridge or fraction of one, may be tied to a lath or any other light stick (see Fig. 24) at distances from 6 to 24 in. apart. The spacings and charges are determined by the character of the soil and depth and diameter of the hole required. Here, again, test shots must be made to determine the most satisfactory and economical method of procedure.

TABLE I.—APPROXIMATE TABLE OF CHARGES OF STRAIGHT 50% DYNAMITE FOR BLASTING DITCH WITHOUT A BLASTING MACHINE

Top width of ditch	Approximate number of cartridges per hole required for ditches of various depths				Number of parallel rows required	Distance between rows in inches
	2½ to 3 ft.	4 ft.	5 ft.	6 ft.		
6	1	2	3	5	1	..
8	1	2	3	5	1 or 2	30
10	1	2	3	5	2	36
12	1	2	3	5	2	42
14	1	2	3	5	2	48
16	1	2	3	5	3	36
18	1	2	3	5	3	42

TABLE II

Spacing between holes in row, in.	10 rods			¼ mile			½ mile		
	Number of holes	Dynamite required using charges per hole of: Half cartridge, lb.	Whole cartridge, lb.	Number of holes	Dynamite required using charges per hole of: Half cartridge, lb.	Whole cartridge, lb.	Number of holes	Dynamite required using charges per hole of: Half cartridge, lb.	Whole cartridge, lb.
18	110	28	55	880	220	440	1,760	440	880
20	99	25	49	792	198	396	1,584	396	792
24	83	21	41	664	166	332	1,328	332	664
26	76	19	38	608	152	304	1,216	304	608
28	71	18	36	566	142	284	1,132	283	566

1 rod — 16½ ft.
10 rods — 165 ft. or 55 yd.
¼ mile — 1,320 ft, or 440 yd. or 80 rods.
½ mile — 2,640 ft. or 880 yd. or 160 rods.

The top cartridge or piece of cartridge is primed with a fuse and blasting cap or an electric blasting cap. (Nothing smaller than a No. 6 should be used, so as to insure perfect detonation.) The lath with the primer on top and charges attached is then placed in the hole (see Fig. 25). If water is in the hole of suffi-

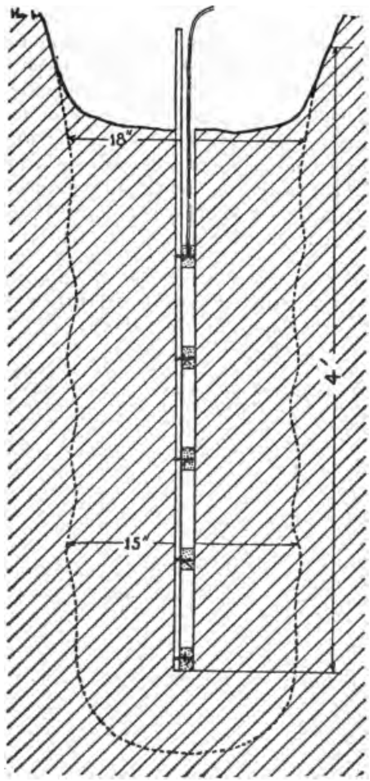


Fig. 25. Method of Loading for Pole Hole Blasting.

cient depth to cover the charges, including the primer, no tamping is necessary. If, on the other hand, the hole is dry, better results may be secured if the hole is tamped at the top about the charge. In tamping the hole care should be taken to see that no dirt or pieces of sod get between the primer and charges

below. In firing, the force of the explosion of the primer explodes the other charges, but if dirt or sod intervenes the charges below will fail to explode. Water transmits the detonation, but dry dirt retards or cuts it off entirely.

In a test shot following the described method in a tight clay soil, an excellent, clean-cut, open hole was blown out 4.5 ft. deep. One-third of a cartridge of straight 60% dynamite was placed in the bottom of the hole; one-third of a cartridge of the same strength eight inches from the bottom, and one-half cartridge of 40% low freezing extra dynamite was placed 20 in. below the top. There was no tamping in this case. Very little hand work was required to clean the hole out.

Another test shot was recently made in a wet blue clay soil. A bore hole was put down 6 ft. deep. Seven charges, each containing one-third of a cartridge of 50% straight nitroglycerine dynamite, were placed 6 in. apart, beginning at the bottom. This blew out a uniform, clean-cut hole, 78 in. deep, which required less than three minutes of hand work to clean out. The walls were compact and hard. The shot was satisfactory in every way.

In pole hole blasting the straight dynamites give good results in warm weather, while the extras and low freezing grades give satisfactory results both in warm and cold weather. The straight dynamites are more sensitive and quicker in their action than the others.

Undercutting Frozen Ground. One of the simplest methods of excavating frozen ground where the depth of freezing is not too great, is to undercut it and to break the unsupported crust with heavy sledges.

Methods of Digging Pole Holes in Frozen Ground. The following is from *Engineering and Contracting*, Dec. 3, 1913.

In northern Minnesota, where the earth freezes to a depth of from 4 ft. to 5 ft. in winter and where consequently the cost of digging holes is high, the following expedient is used to keep down costs. When the top of the hole has been picked out to a depth of 6 in. or more, a tin cup full of gasoline or coal oil is poured into the hole and lighted. The digging is then continued, the burning oil thawing the earth, and from time to time more oil is added. It is said that with the help of about a gallon of oil per hole, the cost of digging can be reduced approximately 15%.

Steam jets have been successfully used. For example, in *Engineering News* for April 13, 1899, a description was given of a method used for thawing frozen ground in order to dig holes for electric light poles, from which the following information is abstracted.

A vertical jet pipe was connected by a tee to a horizontal pipe 24 in. long, capped at one end and connected at the other by nipples and four elbows with a pipe leading to the boiler of a traction engine. The nipples and elbows were provided to allow the necessary play for handling the appliance. To protect the workmen from the steam and to enable them to manipulate the jet pipe, two wooden handles 2 x 4 in. in section and 10 ft. long were connected by stirrups to the two ends of the short horizontal pipe.

This jet pipe was forced down by two men pressing on the handles; as the earth thawed out, the steam carried the particles out alongside the pipe; and as the depth increased more steam would be condensed in the borehole until finally no steam escaped and the outflow was liquid mud. This outfit, which was invented by Mr. James W. Pearl, of Decatur, Mich., would thaw out about 30 holes for electric light poles in a day of ten hours.

Thawing Ground with Steam Pipes. An article by Mr. A. Lenderink, in *Engineering News*, Feb. 18, 1915, gives the following:

An interesting method of thawing ground for trenching was employed during the winter of 1914 and 1915 at Kalamazoo, Michigan. The ground in the streets was frozen 18 to 24 in. deep and this was thawed by the following method: A 10-hp. upright boiler and engine (mounted on a truck so that it could be easily moved about) furnished steam to a 1-in. steam line, laid along one of the outer edges of the proposed trench for a distance of 100 to 150 ft. from the boiler and returned along the other edge. This part of the trench, including the pipe, was then covered with some wooden sewer forms that the city had used for large concrete sewer construction, and the forms were covered with 6 to 8 in. of sand. The pipes were kept off the ground by laying them on a few bricks.

It was found that by keeping steam on the pipe for 24 hr. the frost in the part under cover was entirely removed. The moisture in the thawed ground allowed the men to shovel the top dirt out of the trench without using a pick to loosen it. The pipes and forms were moved ahead each morning and the thawing started for the next day's work.

The cost of thawing, for a trench 3 ft. wide, was 8 to 10 ct. per lin. ft., exclusive of interest and depreciation on the boiler.

A Device for Thawing Holes, made by Hauck of Brooklyn, consists of an oil burning blow pipe which is used inside of an 18-in. length of stove pipe. The ground is warmed and dug out with bar and scoop to the full depth but to a diameter of from 8 in. to 12 in. only. The hole is then filled with the warmed earth, covered and allowed to stand over night. The warmed

earth thaws the adjacent frozen earth so that the hole may be excavated to the full diameter.

Lime for Thawing Frozen Ground. The following is from *Engineering Record,* March 22, 1913. In connection with the sewer construction at West Liberty, Iowa, described in the *Engineering Record* of Mar. 15, 1913, a novel method of fighting frozen ground was used with considerable success. During the winter of 1911 and 1912 the ground was frozen to a depth of about 4 ft., and in this state resisted all efforts of the trenching machine to break it. Finally lime was placed, covering the width of trench to be opened, and was broken up into small pieces and covered with straw, hay or manure. Water was poured upon it so as to slake the lime thoroughly. The covering retained the heat, which with the hot water penetrated the frozen ground sufficiently to enable the trenching machine to make headway. On another job a covering of old boards with a steam jet was found to hurry matters up. This method of thawing ground is now being used successfully by Thos. Carey & Son in Clinton, Iowa, where they have been vigorously prosecuting sewer work all winter.

Thawing Frozen Gravel. In "Methods and Costs of Gravel and Placer Mining in Alaska," by C. W. Purington (U. S. Geol. Survey Bul. No. 263, 1905), various methods of thawing gravel for mining purposes were described substantially as follows:

According to experience in one district the efficiency of a good fire in creek ground was as follows: A fire taking three-fifths of a cord of wood (at $12 a cord) is built against the face of the bank. The pile of wood is 18 in. wide, 2 ft. high and 25 ft. long. Stones are laid up over the pile and a space is left to light the fire. The fire is lighted at 5 p. m. and left to burn until 8 a. m. the next day. The stones, which quickly get hot, are regarded as most efficient in thawing. On a 4-ft. thickness of pay gravel this amount of fire will thaw in the time specified from 5 to 6 cu. yd. This is at the rate of 9.2 cu. yd. thawed per cord of wood, which is considerably less efficient than the method of thawing with steam. Time, delays and awkwardness of the method, moreover, make wood fire thawing the most expensive that can be adopted. The figures per ft. for shaft sinking range from $3.16 to $7.50 in taking gravel from prospect shafts.

The direct application of jets of dry steam to the gravel bank through the agency of driven pipes has been found to be the most efficient method in general practice for thawing frozen gravel. The amount of moisture contained in steam can be judged by the color of a jet of steam issuing from a small brass petcock. If it is transparent or whitish near the orifice it con-

tains less than 2% of moisture. If pure white the moisture is above 2%. A ¾-in. steam hose is run from the boiler to the bank, where it ends in a manifold to which several ½-in. hose lines can be coupled. Each of these small lines ends in a hollow bar about 5 ft. long with a tool steel point which is driven into the gravel and enables the jet of steam to penetrate far into the interior of the frozen mass.

In creek claims exceeding 15 ft. in depth, where solidly frozen ground occurs, the method of drifting with the use of the steam point is as follows.

A 20-hp. boiler, capable of running 10 steam points, is put on the ground, and frequently one or two extra long points are provided for sinking holes. These long points, from 10 to 12 ft. in length, are not so strongly made as the 5-ft. points used in the drifting operations. In some cases pieces of ½-in. hydraulic pipe are used. The point is set up on the ground and steam or hot water is turned on. The time for sinking a hole by this method to bedrock is from 24 to 48 hr. If large flat stones are encountered in the gravel it is sometimes advisable to use strong, specially made points to prevent breaking. The average radius of a vertical shaft thus thawed by a single point is 2 ft. and the hole when cleaned out has a cylindrical or tube shape.

On some of the work the 5-ft. points are used in batteries of four points each. A mallet is used to drive the points into the bank, where they are left from 10 to 14 hr. Each point thaws a block of gravel averaging 6 ft. into the bank, 18 in. on each side of the bank and 4 ft. high. The use of hot water turned into the hose for starting the points is considered good practice. The points must be driven carefully and slowly, and for ten points distributed along a face the average time needed is from one to three hours. The amount of steam required for each point has been found to vary in amount from 1 to 2 boiler hp. The amount of gravel which a point will thaw appears to vary with the length of the point, and this is regulated somewhat by the character of the gravel. The 5-ft. point has been found to be the most economical.

A typical case illustrating the efficiency of the points is the following: Points of Dawson manufacture, 5 ft. long, costing $15 laid down, were used in manifolds of four. They were put in at distances of from 2 ft. 6 in. to 3 ft. apart, and were started with hot water. It took three hours to drive them in. A 12-hp. boiler supplied the steam for ten points, three-fourths of a cord of wood being burned while the thawing was done. In twelve hours the ten points thawed a block of gravel 30 ft. in length by 5 ft. high, 6 ft. into the bank or a total of 33.3 cu. yds. This is

at the rate of 3.3 cu. yds. per point and 44.4 cu. yds. per cord of wood.

Steam Jets Thawing Ahead of Steam Shovel. (H. P. J. Earnshaw, in *Engineering News-Record*, Sept. 13, 1917.) Thirty-four inches of frozen clay, so hard that stones embedded in it could be cut off without loosening them at all, which was encountered on a recent excavating contract, was readily thawed by the following method.

It was impossible to lift or break this frozen crust, and ordinary means of thawing, such as steam pipes under canvas cover, and live steam under canvas cover, proved such a failure that only 4 or 5 in. were thawed out in 36 hours. The plan used was to jet holes with an open-end ½-in. pipe connected to the boiler by a ½-in. hose, the steam pressure quickly melting a hole in the frozen clay and forcing pebbles and small stones out of the way. As fast as these holes were made a ½-in. capped pipe with four ⅛-in. holes bored in it was put in each and left running to thaw out the ground. These pipes were connected in series by short lengths of hose to steam lines run from the boiler. Twelve of these were put in at a time, connected to one line. These were moved back as the shovel worked toward them, requiring only 15 minutes to thaw out a section of the bank so thoroughly that the revolving shovel could dig it as well as if it had never been frozen.

Thawing by Direct Application of Hot Water is described in *Engineering and Contracting*, Aug. 14, 1907, as follows: At a claim on Gold Run, in the Klondike, where it was desired to extract a 3-ft. pay streak of gravel capped by 27 ft. of barren gravel at a depth of 50 ft. below the surface, a small force pump of the ram pattern, with out-side packed valves, was placed in the main runway near the shaft. It drew water from a 6-ft. sump near at hand, to which the workings drained. The pump had 4-in. intake, 3-in. discharge choked to 2½ in., and the water was pumped to the face by means of cotton hose and discharged through a 1-in. brass nozzle at 40-lb. pressure. Six thousand gallons of water were used over and over, and by discharging the exhaust from the pump into the suction the water was kept at a temperature of 150° F. In a shift of ten hours the pump, using 30 hp., thawed and broke down ready for the shovelers 175 cu. yd. of gravel.

Hot Water Thawing. It is stated by Mr. Henry Mace Payne in a paper read before the Canadian Mining Institute, and abstracted in *Engineering and Contracting*, April 17, 1918, that experience in the Yukon District shows that with hot water four times the amount of gravel can be thawed in two-thirds the time

with less than half the fuel necessary when steam is the medium used. An average of 46% of the frozen material in place is ice. When this is melted, the boulders are loosened, so that a thawing process started at bed-rock creates a subterranean cavern, which, as the thawing continues, causes a gradual caving to the surface and a shrinkage in volume of the entire mass.

To drive the thawing points to bedrock a hollow-steel rock-drill cross-type bit was welded to the end of a ¾-in. steam point and a 3/32-in hole was drilled at the top of each of the four flutes to the bit. Thus, instead of one 3/16-in. hole at the end, as in the old point, there are five holes, four in the sides and one in the end, and as a result it is possible to drive the point directly through a boulder.

A frozen boulder when partly drilled through expands from contact with the hot water and splits, allowing the point to drop

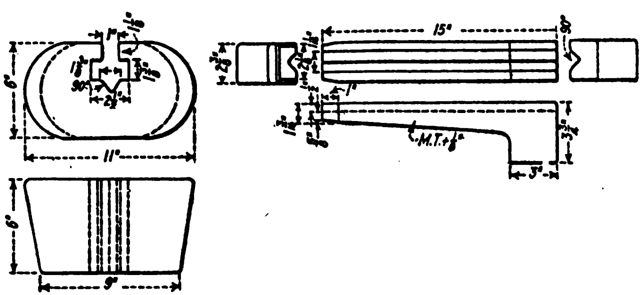


Fig. 26. Anvil Attachment for Thawing Points.

below to the next boulder. Meanwhile the hot water has a sluicing effect from the four side holes, not obtainable with the one orifice only, and thawing proceeds with consequent greater rapidity.

A further advantage of hot-water thawing is the elimination of the possibility of back pressure or suction through the thawing point, with consequent choking by mud, etc., due to steam condensation in the lines, or pressure drop in the boiler.

To facilitate driving of the thawing points and to eliminate the use of ladders and chances for breaking points, anvils weighing about 100 lb. may be forged from old dredge-bucket pins, slotted so as to pass over the thawing point, and held in place by a key. (See Fig. 26.) Handles may be inserted on each side of the anvil and the helper can turn the point as in regular rock drill-

ing, while the operator standing on the ground alongside strikes with a sledge hammer, driving the point until the anvil reaches the ground. The key can then be knocked out, the anvil raised to a convenient height, and the driving operation resumed.

In thawing, the points are regularly spaced in triangular relation to each other 16 ft. apart between any two adjacent points. This establishes a fixed distance from the points to the supply line. Rubber hose is used only during driving, after which a standard pipe connection is put on. Between the pipe connections and the main line ordinary railroad-train hose couplings may be inserted, obviating leaky unions and facilitating connecting and disconnecting operations. Two pairs of point men, each equipped with an anvil, can drive five drill-bit points in 10 hours, viz.: Driving, 6 hr.; pulling, 1½; connecting, 1½, and miscellaneous, 1 hr.

Thawing Frozen Gravel by Hot Water. *Engineering and Contracting*, Oct. 18, 1916, gives the following:

Marked reduction in the cost of thawing frozen gravel in the Klondike District has been brought about by the use of hot water instead of steam. In an article in the *Sibley Journal of Engineering* for September Dr. Henry M. Payne states that during the season of 1915, by the employment of hot water and other improvements, the amount thawed per thawing point was increased 265%; the time required to drive the points was decreased 50%; the average net thawing period was decreased 50%; the fuel consumption per unit thawed was decreased 65%; and the number of points used per unit area (and consequent labor-saving in driving and pulling) was 70%.

During the past four years a systematic study of the thawing problem has been conducted by Dr. Payne, and the whole process has been reduced to a scientific basis.

The actual temperatures, specific heats and specific gravities of the materials to be thawed have been definitely determined and several interesting physical characteristics discovered, as, e. g., it was found that after reaching frost line the temperature drops within the next few inches to the mean temperature of the mass, depending solely on the nature of the material, and not on its depth or on water level.

The steam points, instead of being driven in rectangular arrangement, are staggered in triangular lay-out, thereby reducing the theoretical unthawed segment between the thawed cylinders of ground, or the correspondingly necessary overlap to completely thaw the area.

Experiments were carried on with hot water as a thawing medium instead of steam, the points being driven at varying

distances and depths, and left for various periods and then withdrawn, and excavations made to ascertain their efficiency.

The great loss from condensation of steam was immediately corrected by this method, although the quantity of water required is 3.6 times as much as for steam at the same pressure, the boilers being supplied by injectors and the pipe line being connected with the blow-off pipe.

The next steps were: The substitution of an Ingersoll-Rand drill bit point for the ordinary one on the steam point; the design and construction of a movable anvil to fit over the steam pipe at convenient driving height above the ground, eliminating the moving and climbing of ladders at each point while driving; the use of three-way connections on steam lines; and of standard pipe lengths and train-line couplings in place of rubber hose.

Eventually the thawing point was driven to bedrock at one driving, and thawing started from the bottom up, instead of the reverse, as had always formerly been the case.

Dredging Frozen Earth. *Engineering and Mining Journal*, May 26, 1904, contains a description of an elevator dredge. It worked all winter in Montana. Frozen sod 7 to 15 in. in thickness could be handled by the buckets without blasting, but when thicker than this it was broken by small charges of dynamite, about ½ sticks in a hole for every 10 sq. ft. of surface broken. The winter was mild and the frost was never over 24 in. thick. The sluice was made of sheet metal with an inner lining on sides and bottom of wood between which steam pipes were placed.

Chisel Excavator for Frozen Ground. (*Engineering and Contracting*, Sept. 22, 1909.) A machine that was first used on sewer work at Winnipeg, Manitoba, for excavating frozen ground was operated as follows: A hole was first dug by hand through the frost, and then the machine was put to work chiseling down one side of the hole and elongating it into a trench. The machine then traveled back and forth along one side of this trench, breaking down one side for several feet each trip, and so widening the trench until it covered the whole area. The operating force consisted of an engineer, a fireman, and four helpers.

Briefly described, the machine consisted of a frame platform, mounted on a truck and carrying two hammer guides like the leads of a pile-driver. These leads were not fixed as in a pile-driver but were mounted on wheels, which ran on the top piece of a sort of gallows frame. They were thus capable of being shifted right and left a distance of 5 ft. each way. In the guides was an 800-lb. hammer, attached to bottom of which was a 6-in. diameter bar, from 3 to 7 ft. long, with its lower end forged down to a chisel edge. The drop of the hammer and

chisel was usually about 14 ft. At the center of the platform, just forward of the leads, was riveted a boom, whose outer end was guyed back to the top of the gallows frame. This boom made the machine a derrick for handling frozen lumps of earth excavated by the chisel. A 10-hp. engine and boiler operated the hammer and boom. The machine was invented by Mr. William Hurst.

In excavating a sewer in Winnipeg, the daily cost of operation was as follows:

1 Engineman at $3.00	$3.00
1 Fireman at $2.00	2.00
4 Laborers at $2.00	8.00
Coal and oil	3.50
Rental of machine	5.00
	$21.50

The output on trenching work was about 60 cu. yd. per day, and on foundation work, from 200 to 300 cu. yd. per day.

The work was done when the depth of frost was 5 to 6 ft., and the cost of excavating a cubic yard by pick and shovel was $1.35. Using explosives, the cost has been in individual cases as low as 93 ct. per cu. yd. With machine, the same excavation costs from 11 to 30 ct. per cu. yd.

Breaking Up Clay. A method of breaking up hard clay for a dredge somewhat similar to the foregoing is described in *Engineering and Contracting*, Feb. 12, 1908. The foundation walls for a bridge were sunk through sand and clay, the latter being dark blue and very hard. It was brittle when quite dry, but like leather when under water. A dredge was used to remove the overlying sand but could make no impression on the clay. Accordingly the following method of breaking up the clay was employed: Five double-headed rails each 20 ft. long, and weighing 64 lb. per yd., were riveted together. The two outer rails were splayed outward like a trident and were sharpened. The center rail was also sharpened, and the two others were cut off at about 2½ ft. from the end. This arrangement was worked up and down by a steam hoist, and, being top heavy, when it was driven into the clay it tended to fall over, thus breaking up the clay. In this manner a hole 1 ft. deep and 13½ ft. in diameter could be dug and dredged in 24 hrs.

A Method of Thawing Ground for Trenching is illustrated in *Engineering and Contracting*, March 19, 1919, and is described as follows:

In the construction of the Rideau River intercepting sewer at Ottawa, Ont., work was carried on during the winter months. As the frost penetrated deeply into the ground, the thawing

device shown in the sketch was employed. This consists of a box 6 ft. wide by 1 ft. high, and a steam pipe. The box was placed each night to cover a section of the proposed trench about 60 ft. in length — the amount that would be excavated next day. The pipe had perforations every 18 in. The steam was kept on all night at high pressure.

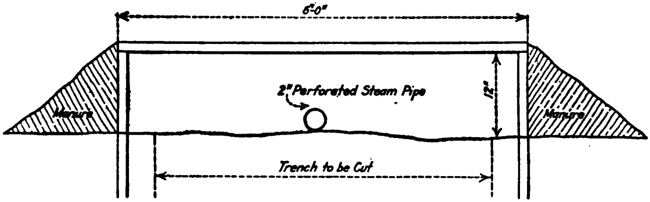


Fig. 27. Thawing Device for Frozen Ground.

Boring Horizontal Holes Under Frozen Crust is described in *Engineering News-Record,* April 19, 1917, as follows:

In steam-shovel excavation required in frozen ground on grade-crossing-elimination work at Mendenhall, Penn., the Good Roads Construction Co. did some experimenting in blasting the frozen crust. The results indicated that the most efficient method was to bore horizontal holes with an earth auger underneath the crust.

The first attempt at blasting this crust was made by punching holes 4 ft. apart, with bars and hammers, through the 14- to 18-in. layer of frost. A quarter-pound of 60% dynamite was used in each hole, the shots being fired separately with a fuse and cap. It developed that the holes were too far apart and the powder too quick for this class of work, the tendency being to blow out small craters without loosening the entire crust. Du Pont low-freezing farm powder was then substituted and the holes placed closer together, on 3½-ft. centers. The loading was increased to ½-lb. per hole and electric firing adopted. This gave much better results, cracks extending from hole to hole, which enabled the steam shovel to take out the crust in chunks.

The best results, however, were obtained after a face had been developed in front of the shovel by boring horizontal holes with an earth auger at the bottom of the frost line, loading them with ¾ lb. of farm powder each and firing them electrically. These holes appeared to confine the expanding gases better than the vertical holes and to secure the maximum heaving effect of the explosive. The crust was more thoroughly broken and the efficiency of the steam shovel increased by this method.

Blasting Frozen Ground with Gopher Holes. In overburden stripping on the Mesabi Range of Minnesota steam shovel operations are continuous throughout the year. Much of the stripping is done during the winter months. The following description of the method commonly employed in breaking up the frozen ground is taken from an article by L. D. Davenport, Chief Engineer Oliver Mining Co., in the *Engineering and Mining Journal.*

Shallow holes, known as "top holes," are used in stripping to break the frost. These are sunk with jumper or hand-drills that have been heated to a dull red; in badly frozen ground steam points have been used. The depth of the holes will vary from 3 ft. to 6 ft. The charge used in blasting consists of 6 lb.

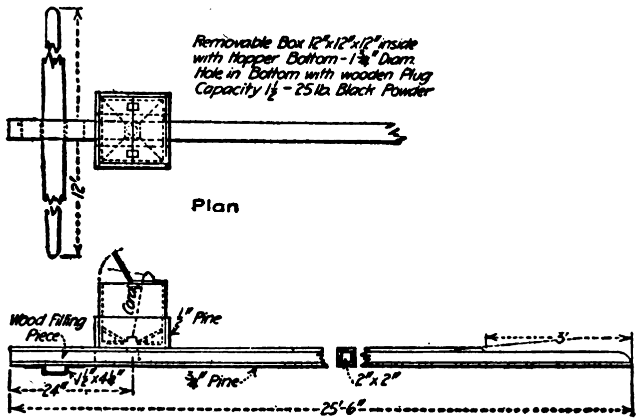


Fig. 28. Details of Loading Device for Gopher Holes.

to 8 lb. of du Pont black powder per hole, depending on the ground. In some cases it is advisable to loosen the surface of the stripping for a considerable area by drilling holes 3 to 5 ft. deep and blasting with light charges of powder before the frost sets in. The air spaces in the ground thus loosened prevent hard freezing.

Stripping banks 15 ft. or more in height are shaken up ahead of the shovel by blasting "gopher" holes. These holes are started at the toe of the bank and are pointed downward at angles of 5° to 10° from the horizontal. "Gopher" holing, when first used, consisted in making the holes large enough to permit a man to enter and work, but frequent accidents caused this method to be abandoned, and "gopher" holes at the present

time have an average diameter of about 15 in. Loose ground is removed with a No. 2 round-pointed shovel blade, the edges of which are slightly turned up, fitted with a 25-ft. handle of 2 or 3-in. diameter. When a hard seam is encountered, it is drilled with a long auger or with a moil, and one or two sticks of dynamite are pushed in with a pointed loading stick and fired with a blasting machine. The loose ground is then removed with the shovel. If a boulder is struck while the "gopher" is being driven, repeated blasting with 60% dynamite will often shatter it sufficiently to allow the hole to be continued. Where it is impossible to blast through a boulder, the hole is bottomed against it, or a new hole is begun a few feet away, depending on the length attained. The limit of length of a "gopher" hole is about 25 ft.

In winter the top of the banks freezes as deep as 8 ft. Unless this crust is broken by top drilling before "gopher" holing is done, the latter usually undercuts the bank, causing slabs of frozen ground to slide down and bury the loading track. It frequently happens, even where the frost has been broken, that chunks too large to be handled by the steam shovel roll from the bank to the track and have to be block-holed by drilling with a steam hose or hot moils and then blasted.

The powder boss determines the size of the powder charge from the height of the bank and the material encountered in digging the hole. With a 25-ft. bank, 15 to 25 sticks of dynamite are used to "spring" or chamber the hole, which is then loaded with 5 to 10 kegs (25 lb.) of black powder. Wooden spoons, 3 in. x 3 in. in cross-section, 2½ ft. long and fitted with 25-ft. handles, are sometimes used to place the powder in the holes. Long wooden launders 2 in. square with a hopper at one end, as shown in Fig. 28, are in general use. A keg of powder is emptied into the hopper, the cover shut and a plug closing the bottom of the hopper is pulled by means of a cord through the cover. The box is oscillated by a 12-ft. cross-handle, causing the powder to run down the launder into the chamber of the "gopher" hole. The long cross-handle allows the powder men to stand 6 ft. on either side of the hole, instead of directly in front, as was necessary with the old-style spoons. Furthermore, the closed hopper protects the powder from the danger of sparks. A detonator, consisting of 2 to 5 sticks of 60% dynamite with two exploders, is placed in the center of the charge. Two electric blasting caps, or else one electric and one ordinary blasting cap and fuse, are placed in each hole. The latter combination is in more general use for the reason that tamping sometimes injures the lead wires from the electric caps. Holes are filled and

tamped to the collar with sand or gravel and are fired in batteries of 3 to 5 at a time. The distance between holes is usually 20 to 25 ft., and the depth of the holes varies according to the shovel cut to be taken. The general rule is to make the horizontal distance between the center of the loading track and the chamber of the "gopher" hole 5 or 6 ft. less than the reach of the shovel. For example, with a Model 91 shovel the distance from the center of the loading track to the bottom of the hole should be 40 ft., as the shovel reach from loading track to toe of bank is about 45 ft.

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Eng. and Con., Aug. 20, 1913, Use of Augers for Boring Blast Holes in Clay.—*Eng. and Con.*, Jan. 20, 1915, Analysis of Concrete Curb Construction.—*Eng. and Con.*, Oct. 18, 1916, Thawing Frozen Gravel.

CHAPTER VI

SPREADING, TRIMMING, AND ROLLING EARTH

Spreading. Trautwine states that a bankman will spread 5 to 10 cu. yd. an hour. Ancelin says 4.5 to 9 of earth, 3 to 8 of gravel, and 2.5 of mud is the average cubic yardage spread per man-hour.

If the work is crowded, or not on a scale sufficiently large to warrant using a leveling scraper, estimate 7.5 cu. yd. spread per man-hour. On more extensive work, where a team can turn around, use a small leveling scraper; or, if there is abundance of room for turning, a road machine with three teams may be used.

After dumping earth from slat-bottom wagons, each load in three piles, I have used a small leveling scraper, which with one team and driver and a helper will spread 50 cu. yd. per hour.

Three teams with a driver and a helper on a road grader will spread 90 cu. yd. of earth an hour from piles left by dump-wagons, spreading the earth in 6-in. layers. Thus the cost will vary from 2 cts. per cu. yd. by hand labor to ½-ct. by a small leveling scraper.

See Chapter IX for illustrated descriptions of leveling scrapers and road graders.

Cost of Grading and Trimming an Athletic Field. D. J. Hauer, in *Engineering and Contracting*, Jan. 9, 1907, gives the following:

The work consisted of excavating 400 cu. yd. of earth from one corner of the field using it to fill up some low places, and in making a small running track, 0.2 mile long. The excavation covered an area of 20,000 sq. ft. and the places over which the earth was dumped were of the same area. The work was to be finished in 18 days after starting, but owing to the fact that on 14 of these days rain fell, it was not finished on time, and the wet weather added somewhat to the cost. Every mark of a cart wheel and a man's foot had to be effaced from the ground. The work was done by contract in the spring of the year.

The wages paid for a 10-hr. day were as follows:

Laborers	$1.25
Cart and driver	2.25
One-horse roller and driver	2.00

The contractor took direct supervision of the work.

The work, listed under the following heads, cost:

Ditching:		
Labor	$ 5.87	
Tiles	5.25	
		$ 11.12

Excavation:		
Labor	$133.13	
Hauling	91.75	
		224.88
Trimming and finishing:		
Trimming	$ 36.50	
Raking	6.50	
Rolling	12.00	
		55.00
Total		$291.00

The ditches were only a foot deep, and a man excavated and backfilled 8.4 cu. yd. per day at a cost of 15 ct. per cu. yd.

For the excavation the earth was loosened by a plow, two of the cart horses being used for this purpose when needed, the greater part of the plowing being done after the men quit work for the day. One-horse carts were used for hauling, there being a driver to each cart. The cost of loosening with pick and plow and of the loading as well as dumping was 33 ct. per cu. yd. at the wages paid; for wages of $1.50 per day the cost would have been 40 cts. The hauling cost 23 ct., but the wages of hired carts were low compared to those paid to-day.

Finishing. The finishing consisted of three items, trimming, raking and rolling. The raking and rolling were done on the embankment, the trimming where the excavation was made. The embankment was leveled with shovels as it was made, and then rolled, after which it was raked with steel rakes and then given a final rolling. This cost 0.8 ct. per sq. yd., or 4.6 per cu. yd. of excavation.

The trimming was done with mattocks and square-pointed, short-handled shovels. Not more than an inch or two had to be dug and the greater part of the dirt was used to fill small holes. The work had to be done carefully and levels were run over it to see if it was to the proper grade. The cost was 10.7 ct. per cu. yd., or 1.6 per sq. yd. Each man trimmed 78 sq. yd. per day.

Surfacing and Dressing Earthwork. On contracts for earth excavation the matter of dressing up and surfacing, both of the place excavated, and of the place of depositing the earth, should be given more consideration than it usually gets. Plans and specifications for this work should be included among those furnished the contractor at the time of bidding. Frequently, there should also be a bidding item for "surfacing."

On wagon road work the dressing and surfacing is sometimes a large per cent of the total cost. On railroads and large embankments if the work is properly managed the cost of dressing should be a very small part of the cost.

Contractors should impress this fact upon their foremen and put into the hands of their foremen, hand or Locke levels, instructing them as to their use, so that all cuts can be taken to grade, and embankments carried to their full height, including shrinkage, as the work is being done. A hand level will be found of vast assistance in this.

If levels are to be run over the finished work, leveling should be done frequently while it is in progress. This may save a lot of costly surfacing.

Trimming. Gillespie says that a man will trim 11 sq. yd., or about 100 sq. ft., surface measure of embankment per hr. The writer is inclined to think that Gillespie's estimate of cost is altogether too high; for a man can pick and shovel 2 cu. yd. of embankment an hour, at which rate he would be able to "trim" to a depth of 6 in. if he covered only 11 sq. yd. of surface per hr., whereas trimming, "smoothing," or "sandpapering" requires a moving of about 2 in. of earth instead of 6 in.

From several careful observations the writer has found that a gang of men under a good foreman will each trim the sod and humps off the hard surface of a cut to the depth of 1 or 1½ in. at the rate of 200 sq. ft. or 22 sq. yd. per hour, at a cost of ⅔-ct. per sq. yd.; and where there was no sod to remove, the soil being sandy loam, the cost was one-half as much or ⅓-ct. per sq. yd. Prior to the world war, Massachusetts contractors bid almost uniformly 2 ct. a sq. yd. for "surfacing" (wages 17 ct. per hour), which includes rolling the finished surface with steam roller. A roadway, including ditches, 36 ft. wide and a mile long, has 21,000 sq. yd. of surface, which at ⅔-ct. is $140, actual cost of trimming. If the total excavation in a mile is 3,500 cu. yd. (which is about the average in N. Y. State), the cost of trimming, distributed over this 3,500 cu. yd., is 4 ct. per cu. yd. of excavation, a cost much greater than a mere guess would lead one to expect.

If "sandpapering" is specified, it is evident from this that the item of trimming must not be overlooked; and the shallower the cuts, the greater its relative importance as an item of cost. A leveling scraper, a road grader, or similar tool will do the trimming of comparatively flat surfaces that are over 6 ft. wide for a very much less sum than by the shovel and mattock method; in fact, the cost is so slight, being merely nominal, that it may then be entirely omitted from the estimate. The author has directed the scraping of a light growth of weeds and grass off the 4-ft. shoulder of a road by going once over it with a "Twentieth Century grader" (a small leveling scraper), at a

rate of 200 sq. yd. per hr. or ten times faster than a man with a mattock would have done it; making the actual cost about ¼-ct. per sq. yd. where the team, driver and helpers' wages were 50 ct. per hr.

As illustrating both poor design and poor management, the Forbes Hill Reservoir experience may be referred to; for very often contractors are compelled by specifications to do just such needlessly expensive work as the following done at Forbes Hill: "In order that the portion of the banks near the inner slope might be rolled as thoroughly as other portions, the bank was built with an extra width of 1 ft. and afterward trimmed to grade." In trimming, the slope of the bank (hardpan rolled) was first plowed, and the material was cast down to the bottom with shovels. The final trimming was done with picks and shovels. Labor cost 15 to 17 ct. per hr.; teams 45 to 50 ct.; and 1,500 cu. yd. were thus trimmed off. The loosening cost 56 ct., and the loading into carts 30.6 ct. per cu. yd., or a total of 86.6 ct. for loosening and loading each cubic yard of earth!

A contractor cannot be too careful in examining specifications for reservoir embankments before bidding.

Cost of Trimming and Dressing Frozen Ground. *Engineering and Contracting*, Jan. 29, 1908, gives the following:

About 1,500 ft. of roadbed had to be dressed up to allow track to be laid at once. At the time the work was done the ground was frozen to a depth of about one foot. Naturally this added much to the cost.

The wages paid were: Foreman, $3.50; laborers, $1.50, and cart and driver, $2.50 for a 10-hr. day. From 14 to 18 men worked in the gang and while the ditches were being dug two carts were used, but after the bulk of the earth was moved only one cart was kept on the work. The cost was:

Foreman, 9½ days	$ 31.67
Laborers, 145½ days	218.25
Carts, 15 days	52.50
Total	$302.42

There was 3,200 sq. yd. of surface to be trimmed. About 2,300 sq. yd. were in the cut and the rest was on the embankment. Only a few places on the fill had to be cut down; the low places being raised with the material from the cuts. The cut was within a few inches of grade throughout, only about 100 cu. yd. being taken out of it, making an average of about 1 in. to be trimmed off the surface. From the ditches 133 cu. yd. were excavated.

The cost per sq. yd. of surface dressed was as follows:

Foreman	$0.010
Laborers	0.068
Cart	0.016
Total	$0.094

Thus the cost was between 9 and 10 ct., when it is frequently done for 1 ct. per sq. yd. on railroads.

From this it will be seen that each man trimmed and dressed 22 sq. yd. per day. Under favorable circumstances he would do about six times as much. Outside of the work in the ditches, only a small piece of the earth could be chipped off the frozen ground at a time. In the ditches picks could be used to advantage, but on the roadbed it was necessary to cut off the few inches of earth with mattocks. Even then it took 10 to 12 pickers to keep three or four shovels busy loading the material into carts. The total cost per cu. yd. of material so moved was $1.30. One man loosened and shoveled in a day about 1½ cu. yd.

These figures show conclusively how expensive this class of work becomes when the ground is frozen. The original cut was shallow, the total yardage in it being about 2,000. Thus the cost of trimming and dressing distributed over the yardage of the cut, makes a cost per cu. yd. of 15 ct.

Trimming a Subgrade. *Engineering News*, June 18, 1903, gives the following: The grading was done with drag-scoop scrapers, wheel-scrapers and wagons, each being used as demanded by the length of haul. Earth was loosened with plows to within 3 in. of subgrade and this last layer then removed with pick and shovel.

The cost of removing the last 3 in. was 2 ct. per sq. yd. with labor at $1.75 per day of 10 hr.

Trimming and Seeding Slopes. *Engineering News*, Oct. 19, 1916, gives the following: A traveling derrick with skips was used in clearing a long cut on the Baltimore & Ohio R. R. near Muirkirk, Md. The north side of the cut for about 2,500 ft. had been badly gullied, and the material washed down had clogged the track ditch. The cut is about 30 ft. deep. At the top of the slope was installed a derrick car consisting of a timber platform or truck mounted on four wheels and carrying a boiler, a 15-hp. double-drum hoisting engine and a stiff-leg derrick with 30-ft. boom. This car ran on a wide-gage track, which was picked up in the rear and relaid ahead as the work progressed. The material excavated was loaded into open flat boxes of 12 cu. ft. capacity, which the derrick raised and dumped to form a broad flat fill about 4 ft. from the top of the cut. This bank serves to stop drainage toward the cut and renders a top ditch unnecessary. The ditch was cleared out and the slope dressed

to a uniform surface. The slope was then covered with street sweepings and sown with grass seed to form a permanent protective covering. The force and organization were as follows: 1 foreman, 1 engineman, 16 men trimming the slope and filling the boxes, 1 or 2 men at guy lines to guide the loaded boxes up the slope and haul the empty boxes back into position, 1 man at the top of slope to trip the boxes and spread the material in the fill, 2 men shifting track, 1 cart and driver to haul coal and water, 1 water boy, 1 night watchman. This force co ld handle about 400 boxes per day. The cost was less than 60 ct. per yd. For seeding the slopes a mixture of alsike clover, blue grass, alfalfa and oats is used. After seeding, the surface is covered with about 6 in. of street dirt or street sweepings from the large cities, this being shipped in cars and distributed by teams and men with wheel-barrows. This method has been found very satisfactory, and after the first season it is easy to maintain the slopes.

Ramming and Rolling. A man can thoroughly ram or tamp in 6-in. layers 2.5 cu. yd. per hr.; but where the soil is not clayey, consolidation may often be more effectually and cheaply done by puddling with water.

A 5-ton roller with a 60-in. face, drawn by three teams handled by one driver, will consolidate about 100 cu. yd. an hr. One team on a 2-ton grooved roller will travel ten times over a 6-in. layer at a speed of 90 ft. a minute including rests, thus consolidating at a cost of about 1 ct. per cu. yd. where team and driver wages are 70 ct. per hr.

As an example showing the highest probable cost of spreading and rolling a reservoir bank where extraordinary care is required, the Forbes Hill Reservoir, described by Mr. C. M. Saville in *Engineering News*, May 13, 1902, may be cited. The material was hardpan (clay and gravel) spread in 4-in. layers by hand, all cobbles over 3 in. in diameter being removed. The sprinkling was done from a water pipe and hose. Corrugated rollers weighing two short tons each, and drawn by two horses, were used. Laborers were paid 15 ct. to 17 ct. per hr., team (and driver) 45 to 50 ct. The dumping of wheel-scrapers and spreading by hand cost 7.7 ct. per cu. yd.; and the rolling cost 3.9 ct. per cu. yd. measured in cut. There is evidence, however, indicating poor management in doing this work.

In reservoir embankments, harrowing may be required, in which case a team and driver upon a harrow may be counted upon to harrow about 100 cu. yd. an hr.

Sprinkling. Sprinkling of embankments, where specified, is usually required to be "to the satisfaction of the engineer"— a

form of wording that always seems like an attempt to hide ignorance under a cloak of ambiguity. Seldom should more water be required than would fill the voids in the packed earth, say 8 cu. ft. of water per cu. yd. of earth; and as a rule not over half as much as required to secure satisfactory puddling.

On a large embankment three sprinkling carts, each drawn by three teams, with one driver, sprinkled 1,000 cu. yd. of earth per day of 10 hr., with short haul. Such carts each held 150 cu. ft. of water weighing 4.5 tons, which is an exceedingly large cart. A sprinkler of this capacity can be loaded from a tank in 15 min., and emptied in the same length of time. Knowing the length of haul and speed of team the cost of sprinkling is readily determined. In the case just given the cost was 2.3 ct. per cu. yd. of earth for sprinkling and about 5 cu. ft. of water per cu. yd. were used.

A man with a good hand pump will raise 1,000 cu. ft. of water 16 ft. high in 10 hr. into a tank, making the cost of pumping in this case by five men for the 1,000 cu. yd. of earth sprinkled, 1.5-ct. cu. yd., when wages are 30 ct. per hr. Had a small engine burning ½ ton soft coal a day and an engineman been employed, the cost would have been about half as much for the pumping item.

Cost of Spreading and Rolling a Reservoir Embankment. The Tabeau Dam in California is an earth embankment 100 ft. high, containing 370,000 cu. yd. of embankment. Mr. Burr Bassell is authority for the following:

The earth (a clay mixed with gravel) was spread in 6-in. layers, sprinkled and rolled. To spread the 2,000 cu. yd. of embankment daily, there were 3 road graders operated by 6 horses and 2 men on each grader. There were 2 rollers, each operated by 6 horses and one driver. There were 2 harrows, and, while Mr. Bassell does not so state, presumably 4 horses and a driver to each harrow. At $1.50 per 10-hr. day for each man and $1 for each horse, we have following cost:

	Per cu. yd. ct.
Spreading	1.5
Sprinkling	0.8
Harrowing	0.6
Rolling	0.8
Total	3.7
Loading and hauling	32.3
General expense (estimated)	2.0
Plant charge (estimated)	1.0
Total	39.0

Test pits dug in this dam showed a weight of 133 lb. per cu. ft. of compacted earth.

The above given yardage relates to the yardage in the embankment, not in the barrow pits.

The rates of wages are merely assumed for illustration. It is probable that laborers received $2 per day at that time and place.

Smoothing and Leveling Farm Land with Tractors. *Engineering and Contracting,* June 12, 1918, describes some experimental work that has been done by the Reclamation Service on the Truckee-Carson project. Land that is too rough to be irrigated by the "boarder-check" system of irrigation is being roughly leveled for this purpose, its final leveling being left to the farmer.

For use with this system of irrigation the land is divided into strips by building low wide parallel levees running with the slope and 60 to 70 ft. apart. The slope of lands between levees, where soils are light, should not be less than 0.2 ft. per 100 ft.; on heavier soils about 0.1 ft. per 100 ft. is allowed as a minimum. The length of strips is from 330 to 660 ft., depending on topography and the economic arrangement for farm laterals and for the removal of surplus irrigation water.

Before work of rough leveling is started a topographic survey is made of the tract. This is used in part to determine the position of the main and lateral ditches and drains, but mainly to determine the direction of slope to be given the lands that are to be leveled. Where the general slope is hard to determine with the eye, 0.5-ft. contours should be taken, when the slope is more pronounced intervals of 1 ft. are ample, and where the tract as a whole has a pronounced slope 2-ft. contours are sufficient.

In preparing a farm unit for rough leveling the prevailing slope, possible water surface elevations and the ditch and drainage system should all be considered. After these factors have been determined roughly, and the farm is plowed to agree with the general scheme of the tract, a line of levels is run around a 5, 10 or 20-acre part of the unit, the size of the tract depending on the general slope. Stakes are then set at the lower and upper end of the land as guides for the tractors doing the leveling. The land is plowed first, but not disked. The sod crumbles under the weight of the equipment, and as the shaping of the land progresses the lumps disappear. In fact, sandy lands do not need to be plowed at all. The land is generally divided into squares or rectangular strips arranged so as to give the minimum ditch length. The final leveling and shaping of the land is done

by the farmer at the time the levees and ditches are constructed. This work is usually done with fresno scrapers.

During the summer of 1917 two tractors were operated, mainly as an experiment and to determine the costs of preparing the land. A flood-lighting system has been devised for working the machines 24 hr. per day. If this proves to be practical, it will be possible to level about 500 acres per month, or about 300 acres if the tractors are worked only 16 hr. per day.

The two machines have worked 16 hr. nearly every working day through the season. The average amount of rough leveling has been 126 acres per month, including all lost time. The average cost has been as follows:

	Per acre
Operation of plant and equipment	$18.50
Depreciation of plant and equipment	5.00
Engineering	1.50
General expense	3.75
	$26.75

To this must be added the $6 per acre for plowing, making the total cost $32.75 per acre. This includes several plowings on some land.

In the tract where work is being done there are thirteen 80-acre units. Some leveling has been done on nearly every unit. As the remaining acreage is noticeably rougher than that leveled, we assume that when the tract is done the average cost will be about $40 per acre. So far the tractors have worked only on unentered public lands. The leveling of uncultivated settled lands has been considered, but no decision has been reached; In fact, the terms at which the Government will require the return of the cost for rough leveling have not yet been determined.

Smoothing Devices Used in Preparing Land for Irrigation. These are described in *Engineering and Contracting*, Jan. 31, 1912.

In preparing land for irrigation it is essential that even the smallest irregularities be smoothed down so that an even distribution of water can be obtained. The land is not necessarily leveled but is graded to an even and continuous slope. Fresno scrapers are used on this work, but home-made leveling devices are preferred.

Rectangular Leveler. Fig. 1 shows a leveler commonly used in California. It is a heavy tool requiring from eight to ten teams to haul, but it will cut down small hummocks, removing shrubs, roots and all. It is solidly built of 4 by 12-in. timbers. One cross-piece is arranged to move up and down by means of a lever, so that the entire weight of the machine can be thrown

on it for cutting down hard knolls. All of the cross-pieces are shod on their faces with $\frac{3}{8}$ by 6-in. steel plates. Heavy chains and eveners are employed to hitch the teams to the leveler, and these are of considerable service in breaking down any shrubs that may be growing on the land. Altogether the weight of this leveler is not far from a ton, including the driver and lever

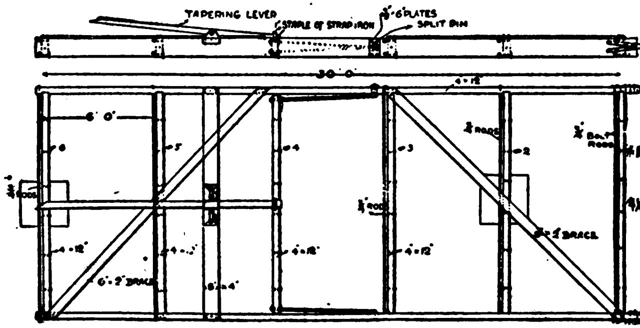

Fig. 1. Rectangular Leveler for Heavy Grading.

operator, both of whom ride on the machine. The rectangular leveler does the best work where the knolls are regular in size and position. Such lands are commonly worked over in bands or strips a half-mile to a mile long and 300 to 1,000 ft. wide.

Modified Buck Scraper or Planer. This device shown by Fig.

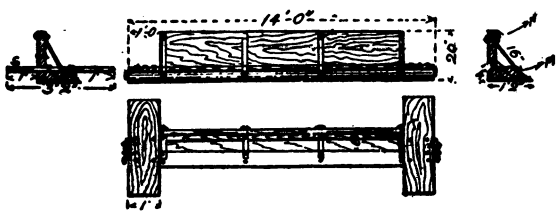

Fig. 2. Planer for Smoothing Graded Land.

2 is designed particularly to give the finishing grade following the rough grading done with scrapers or with the rectangular grader, Fig. 1, hence the name planer. It is L-shaped in section, being made up of a horizontal 4 x 12-in. plank 14 ft. long and a back board of 2-in. plank 18 in. high. The bottom and back are bound together by the steel plate with which the base

is shod and by strap iron brackets. The front edge of the base plate is beveled to a cutting edge. The back board is 1 ft. shorter than the base at each end to provide for the standing boards on which the drivers ride. There are two drivers each handling a four-horse team hitched to each end of the base. By throwing their weights onto the front or rear ends of the foot boards, the cutting edge is tilted down or up to shave off a layer of earth, or to ride over and distribute the soil smoothly. The whole manipulation of the planer, including turning, is easy. As ordinarily used the planer follows the rough grader shown in Fig. 1. When the grader has uprooted and removed the brush and major irregularities, the planer is employed to do the final

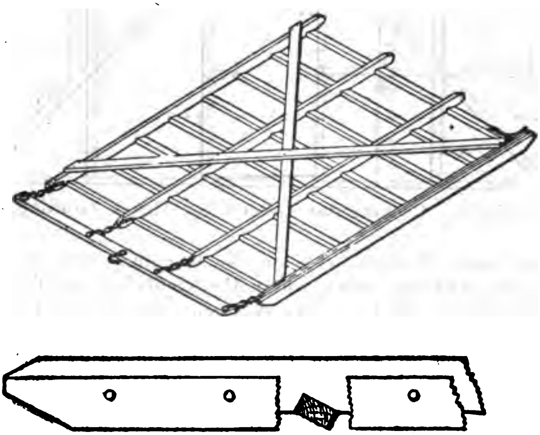

Fig. 3. Grid-Iron Drag for Heavy Grading.

smoothing. Records of work in California give the cost of removing brush and hummocks by the rectangular grader as $1 to $1.20 per acre; the final planing costs from $1 to $1.50 per acre more, making a total cost of $2 to $2.75 per acre for complete grading.

Grid-Iron Grader. Fig. 3 illustrates a home-made grader used in Montana. The outside longitudinals or runners are 16 ft. long and are made up each of two 2 x 6-in. pieces set one higher than the other as shown by the detail drawing. Between these runners and running across the grader are set eight 2 x 4-in. pieces which are shod with steel plates to form scrapers. The inclination of the 2 x 4-in. scrapers is to be noted; also the intermediate longitudinals and the diagonal bracing.

Wheeled Planer. For smoothing the ground after grading the device shown by Fig. 4 is an approved tool. This is also a Montana device. The main structural features are shown by the drawings; it may be noticed, however, that the frame is raised about 14 in. by the wheels and that the scraper blade is steel

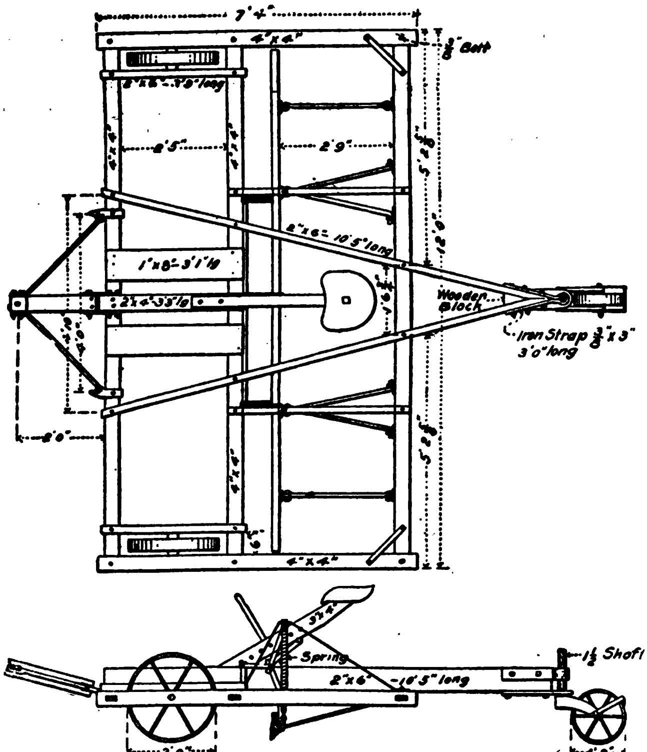

Fig. 4. Wheeled Leveler for Smoothing Graded Land.

shod. This planer is hauled by three to four horses and under competent handling will level from 10 to 20 acres of graded land per day. Bulletin 145, Office of Experiment Stations, gives the average cost in Colorado and Wyoming of preparing land for irrigation as follows:

Item	Per acre
Grubbing sage brush	$1.50
Plowing	2.50
Harrowing	0.50
Grading	1.00
Total	$5.50

Bibliography. "Cost Data," H. P. Gillette.—"Highway Engineer's Handbook," Harger and Bonney (Data on Spreading and Rolling).

Bulletin 145, U. S. Department of Agriculture, Preparing Land for Irrigation.—*Eng. News.*, April 28, 1901, C. R. Coultee on method of compacting lumpy clay on Soulanges Canal.

CHAPTER VII

HAULING IN BARROWS, CARTS, WAGONS AND TRUCKS

In selecting the most economic method of hauling earth over roads, the size of the job and the length of haul are two of the most important factors. There are so many other factors that little is to be gained merely by enumerating them. Perhaps the best way to secure an insight into the problem is first to consider each of the different kinds of plant used in hauling, together with the respective methods and detail costs.

Lead and Haul. The "lead" is the distance between the center of mass of earth in the "cut" or pit and the center of mass of the embankment. The "haul" the distance actually traveled in moving the earth from "cut" to "fill" or embankment, measured one way. The haul is half the round trip distance, and is often considerably greater than the lead.

Types of Wheelbarrows. *Engineering and Contracting*, Dec. 30, 1908, gives the following: There are many styles of barrows made for different classes of work. Those used on earthwork are of the tray pattern. The frame is usually of wood or of a

Fig. 1. Wood Tray Wheelbarrow.

Fig. 2. Stave Tray Wheelbarrow.

combination of wood and steel, wheels are of wood or steel from 15 to 21 in. in diameter. Large wheels make the barrow easier to propel. Steel wheels are preferable to wooden wheels on account of their greater durability. The trays are made either of wood or steel. When only earth is being handled steel trays are

Fig. 3. Steel Tray Wheelbarrow.

to be preferred, as the trays do not sift the dirt over the runways, and the dirt dumps easier, especially if wet. When there is much rock in the excavation the wooden trays give better service and are more economical. They get out of order more easily than the steel trays but are easily repaired. They are not

so apt to be bent out of shape from rough handling, and for that reason are superior to the steel for handling rock.

All-steel tubular barrows are made, the entire barrow and running gear being of steel. They are too heavy for earth excavation. Such barrows weigh from 70 to 125 lb., while steel trays on wooden frame or running gear weigh from 55 to 70 lb. and the wooden tray barrow weighs from 40 to 60 lb.

Runways of the same kind should always be used for wheelbarrows. The common practice for level short hauls is to lay 1-in. planks on the ground with their ends butting together. Where one man only has to wheel a barrow over the runway, and the planks are changed frequently, such a runway is economical and answers the purpose very well, but when a number of barrows are to go over the runway the ends of the boards should be nailed to a small sill sunk into the ground, so as to prevent the boards from being knocked out of place. Good runways quickly pay for themselves, as to delay a long line of barrows only a few minutes, to straighten out or repair a runway, means to waste considerable money. Where runways are not laid directly on the ground, but are elevated, 2-in. planks should be used, and the runway should be at least 24 in. wide. They should be substantially built, so that there is no motion or swaying to them, as the men wheel over them, or else the barrow pushers will slacken their pace; this is especially true when going on an incline. Steep inclines that are short, men go up easily, but long inclines, though not so steep as short ones, men push their barrows up slowly. In either case a strongly built runway is needed. To obtain good work men must be made to believe they are safe from injury while at their work.

A Barrow with Special Dumping Device is described in *Engineering and Contracting*, Jan. 15, 1913.

A wheel barrow which is dumped by pushing down on the handles and with half the work, it is claimed, that is expended in lifting the barrow in dumping by the ordinary method is illustrated in Fig. 4. The barrow calls for little description. When loaded, the steel body rests on the frame in virtually the same position in respect to the wheel and handles as does the body of the ordinary barrow. It can thus be dumped like an ordinary wheel barrow by tipping sidewise or by lifting the handles and dumping over the front edge, or it can be dumped as shown by the illustration. In dumping by pushing down on the handles it is easy to regulate the outflow to a thin stream in filling narrow forms or by a quick downward thrust to discharge the whole load suddenly. This barrow is known as the

Long Self-Dumping Wheelbarrow and is sold by Miller & Coulson, Pittsburgh, Pa.

Costs with Wheelbarrows. Barrows are not economic except in muddy places where horses would mire, or in narrow confined places, or in moving very stony soils short distances, or where the quantity of earth is small.

Trautwine assumes that a man will load and dump a wheelbarrow in 1.25 min., the barrow holding $1/14$ cu. yd., and that a man will travel 200 ft. a minute. He further allows 10% "time lost" in rests. His tables of cost are about right for hauls of ordinary length, such as a 100-ft. haul, but are grossly

Fig. 4. Long Self-Dumping Wheelbarrow.

in error for short hauls, as for 25 ft., where, by his false assumption that a barrow can be loaded in 1.25 min., he makes an output of 25.7 cu. yd. in 10 hr. per man, the actual output being not much over half as much. The error arises from a short-time observation where insufficient time was allowed for necessary rests.

From careful observations the author has found that a man walks at a speed of 250 ft. a minute, and loses $3/4$ min. each trip, dumping load, fixing run plank and resting; and that it takes 2.25 min. to load a barrow holding $1/15$ cu. yd. place measure of earth already loosened (rate of loading being 1.8 cu. yd. an hr.), and in this the author is confirmed by Cole's observations (see Gillespie) on the Erie Canal.

Wherever the word "haul" is used, the distance, one way, from the point of loading to the point of dumping is meant.

In repairing breaks in a levee where the material was very

sticky adobe clay, Mr. Specht made the following observations as to cost: Haul 208 ft., rise 7 ft., load in wheelbarrow 1/7 cu. yd., 7.5 min. per round trip; output per Chinaman on wheelbarrow, 10.8 cu. yd. in 9.5 hr. of actual working time.

10 Chinese on wheelbarrows, at $1.50	$15.00
3 Chinese a $1.50	4.50
1 White foreman	2.50
108 cu. yd. per day at 20.4 ct.	$22.00

It will be noted that the load of a wheelbarrow given by Specht is double that ordinarily given. The author believes it to be misleading, since 1/7 cu. yd. of clay would weigh 350 to 400 lb., and not even a Chinaman would move such a load as that day in and day out. Based upon the data given in this and preceding chapters we have:

Rule. To find the cost per cu. yd. of picking, shoveling, and hauling average earth in wheelbarrows, multiply the wages of a laborer per hr. by one and one-sixth and add one-third of an hr.'s wages for each 100 ft. of haul. When wages are 30 ct. per hr. this rule becomes: To a fixed cost of 35 ct. add 10 ct. for each 100 ft. hauled.

Capacity of Wheelbarrows. Mr. James H. Harlow (*Engineering News*, Sept. 21, 1905) found, when removing earth filling from one cofferdam and placing it in another, that 7,959 barrow loads held 454 cu. yd. by measurement, or 0.057 cu. yd. or 1.54 cu. ft. per barrow. This material was a sandy loam weighing 80.3 lb. per cu. ft. When removing gravel from a bar at Davis Island, he found that 23,484 barrow loads equaled 1,228 cu. yd. by measurement, or 0.0546 cu. yd. or 1.47 cu. ft. per barrow.

Wheelbarrows Loading into Cars. At Portland, Oregon, in 1883, a large bluff was excavated at the rate of 153,000 to 183,000 cu. yd. per month by wheelbarrows and horse-scrapers loading into cars. This work is described in an illustrated article by Mr. George B. Francis in *Engineering News*, Nov. 28, 1885.

Two platforms each 700 ft. long and 40 ft. wide were built parallel with the foot of the bluff. Beneath each platform were two standard gage tracks on which flat cars with side-dump boxes were drawn by locomotives; each car held about 6 cu. yd. place measure. The material was dumped into the cars through holes 20 in. square.

The earth was loosened and thrown down the slope by blasting with Judson powder on the top and slopes of the bluff. On one platform 600 Chinamen with wheelbarrows loaded the cars, and on the other horses and scrapers. The rivalry between these gangs resulted in efficient work.

The first month, when part of the earth was dumped into water, the material shrunk 10% from place measure to measure in the fill; the second month 8%, and the first 416,000 cu. yd., 3.4%.

Cost of Wheelbarrow Work at the Albany Filter Plant. Mr. Geo. I. Baily, in a paper read before the American Water Works Association in 1901, gives the operating cost of the Albany Filter Plant. He states that the ordinary wages of $1.50 per day of 8 hr. was paid but that efficient work was insisted upon.

"A part of the success is due to the attention which we have given to details of the work. We have endeavored to improve not only the work of the men and to simplify it, but to furnish them suitable tools. On the start for scraping we used the ordinary straight edge, D-handle shovel. We learned that it lamed the backs of our men and they could not work to advantage. We abandoned these shovels for long-handled shovels, which would allow the men to keep in a more erect position, and to overcome the slower handling of the new shovel we widened the blade to 12-in., and with these shovels our men scraped more than 100 sq. yd. an hr.

"In the running plank used for wheeling out scraped material we found that to give a proper foundation and width we had to use two of the ordinary 10- to 12-in. planks, and then the service was not good. We had planks specially sawed 14 in. in width, and one of these planks answers the purpose better than two of the others. They are placed as speedily as one of the other planks and the time is therefore reduced one-half. The ordinary wheelbarrows used were not acceptable. On the grades that our men had to go the weight was shifted on the men's arms instead of being carried on the wheel and we therefore re-adjusted on the wheels, giving a proper distribution of weight and saving the strength of our men."

Comparative Cost with Wheelbarrows and Carts. In excavating for the filter bed at Brockton, Mass., wheelbarrows and one- and two-horse carts were used. The comparative cost of these vehicles is given in Fig. 5. In many cases the haul was up an incline and it was found that in wheelbarrow work a lift as great as 5 ft. per 100 made no apparent difference in cost. The time taken in returning with the empty wheelbarrows was 60% of the total time occupied per round trip, which proved that the work was under the direction of inefficient foremen.

The cost of spreading earth on the embankment amounted to 0.75 ct. per cu. yd., and is not included in the diagram. Wheel-scrapers were not used very often, as the number of roots left in the ground after grubbing, and the necessity for removing

them from the embankment material, precluded their use. When wheelscrapers could be used the cost of hauling 125 ft. varied from 5 to 6 ct. per cu. yd.

About 15 cu. yd. per man per day were handled. One foreman was employed to each 16 shovelers.

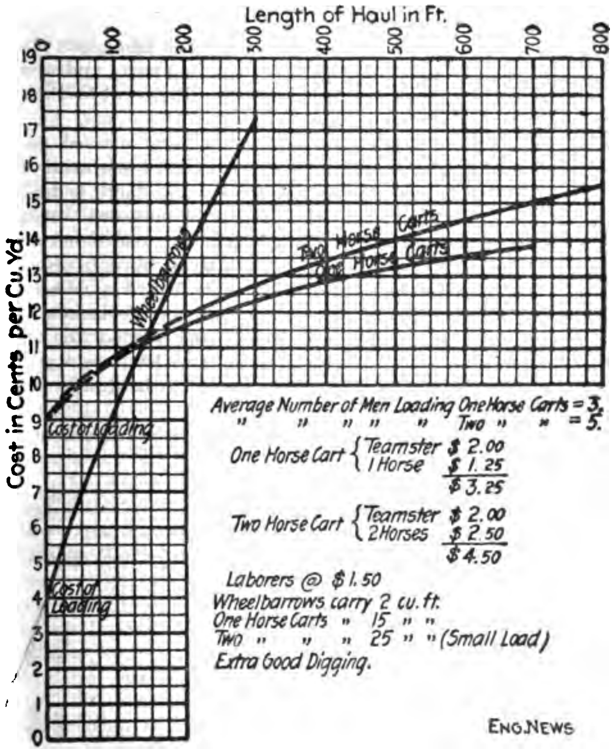

Fig. 5. Relative Efficiency of Wheelbarrows and One and Two-Horse Vehicles in Moving Earth on Brockton Filter Beds.

Excavating Earth and Hardpan for a Creek Change. *Engineering and Contracting*, Aug. 19, 1908, gives the following:

The work described was the changing of the channel of a small creek in the Cumberland Mountains, in connection with the construction of a new line of railroad. The located railroad

crossed the creek twice within 300 ft. and to make a diversion of the stream meant the saving of a 20-ft. arch culvert.

The new channel was made 20 ft. wide on top, 15 ft. on the bottom and had an average depth of 6 ft. It was about 250 ft. long. The top 2½ ft. was a sandy clay, while the rest of the material was a hard cemented gravel. This had to be blasted before it could be shoveled.

The blasting was done with dynamite, holes being put down in the gravel in series, being spaced 5 to 6 ft. apart, and about 15 holes shot at one time, with a battery. Picks were then used to loosen the material.

Under the specification cemented gravel was classed as loose rock, and the engineers classified the excavated material as 400 cu. yd. of earth and 600 cu. yd. of loose rock, there being in all 1,000 cu. yd. of excavation. The excavated material was placed in an adjoining embankment, the earth being loaded onto wheelbarrows. The haul averaged 50 ft. Boards were used as runways. When the work commenced a man loaded a wheelbarrow and pushed it to and from the dump, but, as the trench became deeper, one man stayed in the trench and loaded the barrow, while another operated it. However, as two barrows were used, one being loaded while the other was going to the dump, it meant a wheelbarrow for each man.

Cost of Excavation. The total cost of the work amounted to the following:

Foreman, 22 days, at $3.00	$ 66.00
Laborers, 188½ days, at $1.25	235.63
Blasting	47.68
Total	$349.31

The average cost per cu. yd. was:

Foreman	$0.066
Labor, loosening, shoveling and wheeling	0.236
Blasting:	
Labor	0.025
Explosives	0.022
Total	$0.349

The cost per cu. yd. for each class of material excavated was as follows, being a comparative cost to the price paid for each class of excavation:

Earth:	
Foreman	$0 042
Labor	0.148

Blasting:	
Labor	$0.015
Explosives	0.013
Total	$0.218
Loose rock or hardpan:	
Foreman	$0.083
Labor	0.297
Blasting:	
Labor	0.031
Explosives	0.026
Total	$0.437

One man loosened, loaded and wheeled 5¼ cu. yd. per day, which is a fair day's work in this class of material and under the conditions named.

Two valuable lessons are to be learned from this job. The first is a lesson for the contractor. This excavation should never have been made by hand, but instead teams with drag scrapers should have been used.

This work could have been done cheaper with drag scrapers, even if they had to be bought new and their entire cost charged against this job.

It would have been cheaper yet to have dammed up the old channel and excavated a ditch 8 to 10 ft. wide, just room enough for scrapers. The stream could then be turned into this ditch and would widen it to the required size by natural erosion. Cheaper material than cemented gravel could have been borrowed for the embankment.

"Station Work" on a Railway Embankment. Wilmer Waldo, in *Engineering and Contracting*, Dec. 4, 1907. "Station work" is excavation that is let in small contracts, covering one or two surveyor's "stations" of 100 ft. in length. A contract is usually taken by one or two laborers in a gang. Embankments are built of material taken from either side of the right of way at a distance of 4 or 5 ft. from the toe of the fill. No further restriction is made concerning borrow pits except that they must be connected by ditches for the sake of drainage.

"Station work" is usually done in places inaccessible to teams or where stumps make team work uneconomical. It seldom pays where the depth of cut or height of fill exceeds 4 or 5 ft.

During the summer months the custom among some station men is to do their work partly at night, laying off through the heated part of the day. Station men are not available in great numbers in seasons of extreme heat or cold, preferring to follow

the mean temperature either north or south. They migrate in pairs and often work in partnership, but it is customary to furnish separate estimates of equal value to the two partners. The contract and estimate system in this work does away with a general pay day, which keeps the majority of the men working all the time and eliminates the timekeeper and disagreements in regard to time. The station man expects payment of his estimate immediately upon completion and acceptance, which is arranged by a draft on the nearest bank, unless it is too far away. If no bank is available, the paymaster takes up all estimates due every fifteen days, or any authorized party can take them up at any time on the work.

In considering the cost of this work it must be remembered that there are general expenses to the owner which would not enter into a larger contract of the ordinary kind. Camps must be maintained and there must be some one to supervise and estimate the work of the station men. The cost will be less where many men are employed.

The work upon which the following costs are based was done in Southeast Texas during the months shown, and embraced nearly every kind of material, the majority of it being in low swampy country, subject to overflows in one season and getting very dry and hard in others. A large part of it was sticky clay where the borrow pits were filled with grubs, stumps and roots, requiring the constant use of a mattock. Even in places where the stumps are thick, if the earth shovels well without the use of a mattock or any breaking, station work can be done cheaper than the ordinary team work under good conditions. Team work similar and adjacent to the station work shown in the tables was done at an average cost of 27½ ct. per cu. yd.

WORK BY STATION MEN,

Sections 1 to 8

Total cu. yd. moved	4,800.2
Average rate per yd.	14.1
Average yd. moved per man day	10.7
Maximum yd. moved per man day	20.0
Minimum yd. moved per man day	5.2

Nearly all the station men made daily wages amounting to more than $1.50, while one-third of them made more than $2.00, one man going up to $2.82. This man handled 20 cu. yd. per day, loading and transporting it in a wheelbarrow. The bank was a low one, as the cubic yards in a 100-ft. section were only 91.

The costs for station men in Camp No. 12 were as follows:

1906. June, July, August, September, October, November, December, January to February 22, 1907.

To amounts paid station men —	
48397.2 cu. yd.	$ 7,560.36
To amounts paid labor for grubbing, driving team, etc., moving and about camp	$ 686.00
Team time	166.80
Foreman in charge of work and camp	620.00
Superintendent	62.66
	$ 1,535.46
	$ 9,095.82
To amounts paid cook	$ 516.60
Flunkey	108.15
Groceries	2,046.44
	$ 2.671.19
Credit:	
By board collected from station men	$ 1,240.05
Board collected from labor, foreman, cook, etc.	763.90
	$ 2,003.95
	$ 667.24
To interest on investment of tools, etc.	$ 347.90
	$10,110.96
Cost per cu. yd. for grubbing and labor around camp	$0.0142
Cost per cu. yd. for foreman and superintendent	0.0141
Cost per cu. yd. for hauling, etc., and excess of cost of mess over board collected	0.0173
Cost per yd. of interest on investment in tools, etc.	0.0072
Average price paid per cu. yd. as per crontacts	0.1562
Total per cu. yd.	$0.209

It is of interest to note that a gang of laborers, being paid by the day, working under a foreman, moved 1,549 cu. yd. at a cost of $387.34, making a cost per cu. yd. of 25 ct. This was 4 ct. more than the cost of the work when let by contract to the men.

Carts. The method of hauling with one-horse two-wheeled dump-carts is especially adapted to work in narrow cuts, basement excavations, and wherever the haul is short; but in such places wheel scrapers are ordinarily better, unless the haul is over street pavements.

The great advantage that carts possess over wagons is ease of dumping (one man can dump them) and especially of dumping into hoppers, scows, etc. The data of Morris, who kept account of the cost of moving 150,000 cu. yd. of earth with carts, are the most reliable in print. In his work one driver was required for each cart. Trautwine erroneously assumes that one driver can attend to four carts. For the short hauls upon which carts are ordinarily used one driver can attend to not more than two

single horse carts. Morris found the average speed to be 200 ft. a minute, and the average load 1/3 cu. yd. (bank measure, equivalent to 0.37 cu. yd. place measure) on a level haul; 1/4 cu. yd. on steep ascents, and there were 4 min. of "lost time" loading and dumping each trip. As above stated, the cost of picking and shoveling average earth is one hour's wages per cu. yd., while if earth is loosened by plow the cost of loosening is about 1/20-hr. wages of team and driver, and the cost of loading plowed earth is 2/3-hr. wages of laborer per cu. yd.

Upon these assumptions, and accrediting a driver to each cart with an average load of 1/3 cu. yd., we have:

Rule. To find the cost per cu. yd. of plowing, shoveling, and hauling "average earth" with carts, add together these items:

1/20-hr's. wages of team and driver and helper on plow;
2/3-hr's. wages of laborer shoveling;
1/4-hr's. wages of cart horse and driver for "lost time."

To which add 1/20 hr.'s wages of cart, horse and driver for each 100 ft. of haul. With wages of a man at 30 ct. and of a horse at 15 ct. per hr., this rule becomes: To a fixed cost of 35 ct. add 2.25 ct. per cu. yd. per 100 ft. of haul.

Fig. 6. Two-Wheeled Cart Made by John Deere Plow Co.

If one driver attends to two carts, as is very often the case, the hauling item is 1/40 hr.'s wages of a man and two horses, or 1.5 ct. per cu. yd. per 100-ft. haul at wages above given. In cities where streets are level, and hard, even if not paved, one-horse carts holding 2/3 cu. yd. are used; furthermore horses travel faster than the 200 ft. per minute given by Morris on railroad work, 220 to 250 ft. a minute being the speed at a walk over hard level roads. With large 2/3-yd. one-horse carts and one driver to each cart, the cost of hauling per cu. yd. per 100 ft.

is therefore, $\frac{1}{45}$ hr.'s wages of horse and driver, or 1 ct. per cu. yd. per 100 ft. of haul.

Cost with Carts. *Engineering and Contracting*, Jan. 22, 1908, gives the following:

The job was earth excavation in the construction of a railroad. A cut was taken out with carts, which were loaded by men using short handled shovels. The work was done in the late fall and early winter, when a fair amount of rain fell, but snow falls did not occur. At night the ground froze to a depth of a few inches, and was generally thawed out by the sun during the day. This made the runway muddy and made some of the shoveling harder. The material was red clay that readily absorbed water. The average length of the haul was 900 ft.

The earth was loosened by picks, two pickers keeping three shovels going. Three men shoveled into a cart, two carts being loaded at one time. Four carts were used, one driver attending to two carts, which he took to the dump together. One man on the dump, with the aid of the driver, dumped the carts.

The wages paid for a 10-hr. day were as follows:

Foreman	$3.50
Laborers	1.50
Water boy	1.00
2 carts and 1 driver	4.50

The cost per cubic yard of doing the work was:

Foreman	$0.050
Picking	0.080
Shoveling	0.130
Dumping	0.021
Water boy	0.014
Hauling	0.110
Total	$0.405

The output of this gang per day was 70 cu. yd. This is a high cost, as a greater yardage should have been excavated. The pickers loosened about 18 cu. yd. per man day, while about 11 cu. yd. per man day were shoveled. The man on the dump took care of 70 cu. yd. per day. A careful analysis of this and a comparison of costs of similar work show that the cost of hauling is a little low, while the other costs are all high. This leads to the conclusion that there were not enough carts for this length of haul.

As the foreman was experienced and realized that he was short of carts, he did all he could to keep them going continually and loaded them as heavily as the ground over which he had to haul would permit. The result was that he worked the horses harder than they are ordinarily worked, as will be noticed from the cost

of hauling, which was 11 ct. for a distance of 900 ft. With the wages given above, the cost of hauling per 100 ft. with carts would be about 1 ct., and adding to this the lost team time the total cost should have been for a 900-ft. haul about 12 or 13 ct., while the cost, as stated, actually was 11 ct. That the foreman did his work well is evident from the fact that with a lack of carts that was bound to make his men idle at times waiting for the carts to come back from the dump, he got an output of about 11 cu. yd. from his shovelmen per day.

If two more carts had been used, the shovelers could no doubt have loaded 14 cu. yd. to the man, and instead of using only three men loading to the carts four men could have been employed. This would have made the output per day 112 cu. yd. instead of 70. Thus a saving on the total cost of nearly 20% could have been effected.

With the material that had to be excavated, a man could readily loosen with a pick, by caving in a bank, from 25 to 30 cu. yd. per day, and a man could load into a cart with a shovel 14 cu. yd. The dumpman could easily have cared for the 112 cu. yd. that were sent to the dump.

The costs as given illustrate in a striking manner how one detail of a job that is not properly managed can materially increase the cost of all the other details and that of the whole job and yet that particular cost may be low. Such facts can only be learned by keeping detail cost data and then carefully analysing them.

High Cost of Railway Excavation with Dump Carts. *Engineering and Contracting*, Feb. 10, 1909, gives the following data:

The excavation was made on the grade of a railroad in taking out several small cuts, there being 1,743 cu. yd. in the combined cuts. The material was a sandy clay, and the average haul was 500 ft. The work was done in the fall of the year with good weather conditions, there being but one rainy day during the time. With this class of material, without any stones in it and the depth of cutting and length of haul, the excavation was ideal wheel scraper work, but as the railroad company did not own any scrapers, it was decided to hire carts and do the work with them.

The earth was loosened by a plow, but the plowing was not done well enough, so that some of the men had to pick it. Naturally using a plow prevented the material being worked to a breast and the carts were hauled over the loosened material. This made the hauling hard for the horses and prevented full loads from being carried, and also compacted the loosened mate-

rial somewhat. An average of 17 carts were worked with 58 men and 3 foremen. A single foreman in charge of 29 men, with men and carts scattered over a cut, resulted in poor work. The men clustered around a cart and loaded it as they would a wagon, and, using short handled shovels, the amount of work that could be done in a day was reduced over the number of cu. yd. that could be loaded into a cart at the end with the tail gate out. With such a large number of men per foreman it was also possible for the men to loaf.

A 10-hr. day was worked and the following wages were paid:

Foremen	$2.50
Laborers	1.50
Carts and driver	3.00
Plow team	9.00

The cost of the work was as follows:

Foremen	$ 52.50
Laborers	610.50
Cart work	357.00
Plowing	36.00
Extra work	11.50
Total	$1,067.50

This gives a cost per cu. yd. as follows:

Foremen	$0.030
Plowing	0.020
Laborers	0.350
Hauling	0.205
Extra work	0.005
Total	$0.610

The extra work consisted of digging some ditches after a rain to drain off the water, two foremen and 12 men being engaged on this for half a day.

The very high cost and poor work is shown by the fact that a man only shoveled 4¼ cu. yd. of a material, that could be classed as average earth, in 10 hr. A man should have shoveled, after the material was loosened, 14 cu. yd. in 10 hr.

If scrapers had been used the cost per cu. yd. should not have exceeded 25 ct.

Types of Wagons. A series of articles appearing in *Engineering and Contracting*, Feb. 3 to Apr. 14, 1909, describes the various types of wagons and name of manufacturers on the market at that time at considerable length. A brief abstract of these articles is here given.

The first style of wagon used for earth transportation was the kind now found in common use on farms. This wagon consists of the ordinary running gear with front and back wheels con-

nected by a coupling pole and with wheels having 2-in. tires. The body is a rectangular box made of 1-in. planed boards bound on top with strap iron. The difficulty of dumping this wagon led to cutting holes in the bottom which were covered with boards. These were lifted with a pick, spilling part of the load and leaving holes through which the rest could be easily shoveled.

The idea of dumping through the bottom brought into use the slat bottom wagon. This consisted of the same style running gear. On the bolsters 2- by 4-in. scantlings were placed to make the bottom of the wagon body; 12- to 14-in. boards were used for the sides of the body. Bottom and side boards were worked down at their ends with a draw knife so as to offer a convenient grip. The wagon was dumped by the driver and dumpman lifting these boards one by one. Dumping required about 3 min.

The running gear of farm wagons being found too light for continuous use with heavy loads of earth, heavier running gear with 3- and 4-in. tread tires was made for use on construction work. For many years this heavy running gear with the slat bottom body was the standard wagon for earth work.

Bottom Dump Wagon. The slat bottom wagon has been largely replaced by various patent self-dumping wagons of which the bottom dump forms the largest class. The bottoms of these wagons consist of two hinged doors which are usually held in place by chains and are released to dump the load. They are built of wood and steel, in capacities of from 1 to 5 cu. yd. The front wheels go under the body, making it possible for a team to turn in its own length. Mechanism is provided by means of which the driver can close the hinged bottom while the wagon is in motion.

End Dump Wagons can be divided into two divisions, namely those with tail gates and those without tail gates. Those without tail gates generally have the bodies built of steel, and the body is built of such a shape that the load is discharged by gravity when the wagon bed is tilted for dumping. One advantage that this style of wagon possesses is that none of the load can spill or leak out unless too much of a load is placed on the wagon. This style of wagon is not often used for earth excavation as the wagon is quite heavy, and owing to the shape that is given it, so it will dump, its carrying capacity is reduced.

Those with tail gates are used for earth transportation, and several styles of this class of wagon are in common use in New York City. For dumping into hoppers or bins, and through chutes, or onto scows and barges or into railroad cars they are better adapted than bottom dump wagons, as the horses can be

backed up to the dumping place. For the above listed classes of work and for dumping on piers and wharves this style of wagon is well adapted.

In loading wagons by hand the height of the wagon body is of great consideration. Every inch additional height decreases in the amount of earth that a man can load in a day.

The height of the top of the sides of the ordinary dump wagon,

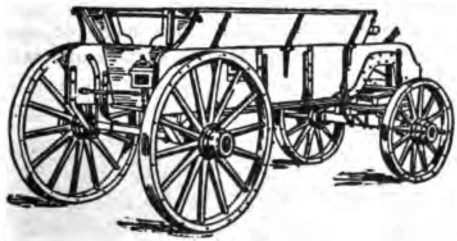

Fig. 7. Bottom Dump Wagon Made by the Watson Wagon Co.

of 1 cu. yd. or 1½ cu. yd. capacity, is from 4.5 to 5 ft. A man at this height will shovel with a short handled shovel about 13 cu. yd. in 10 hr. Over this height to increase the height of the sides of the wagon by 6 in. decreases the amo nt shoveled per man day by about 10%. The reason for this is that in order to cast the earth into the wagon the man must first straighten up his back, after he has filled his shovel, and then by another motion he casts his load into the wagon. With long handled shovels,

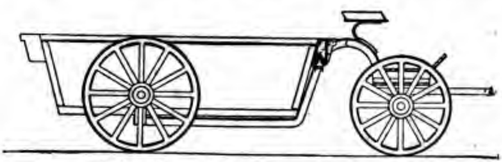

Fig. 8. End Dump Wagon.

in average earth or good clay, men have been known to load into wagons between 14 and 15 cu. yd. in 10 hr., and to increase the height of the wagon 6 in. decreased the amount loaded per man day by about 7%, until the height reached 8 ft.

Special Dump Wagons. One of these, the invention of George Penine and D. L. Hough, was used in the building of the Pennsylvania R. R. tunnels under New York City. A large derrick

skip made in two sections, which were hinged at the top and fitted with latches at each end near the bottom, was used in the tunnels on trucks as the body of a car. This was hoisted to the surface. On the street level the skip was placed on a wagon, thus becoming a wagon body. At the dump the skip was dumped into a scow by a derrick, a light rope being used to trip it in dumping. The capacity of the skip was 3 cu. yd.

Similarly on the Illinois tunnels in Chicago a wagon invented by Wm. J. Newman was used to carry spoil to the dump. The body of the wagon was a square box made of steel and was picked up from the running gear by a derrick and raised over the

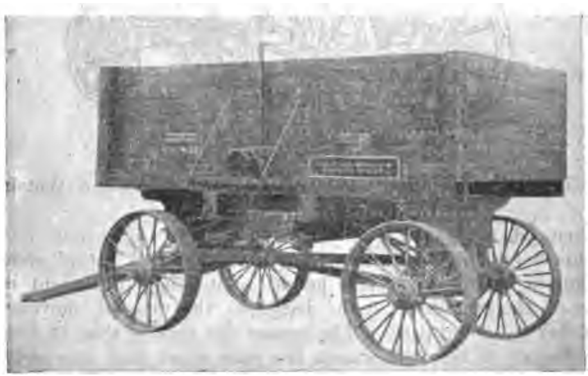

Fig. 9. Center Dump Wagon Made by Russell and Company Capacity 8 to 10 Tons.

stock pile where the bottom of the box dropped down, spilling the load.

Another type of wagon, requiring a machine to dump it, is made by the Bergen Point Iron Works, 149 Broadway, N. Y. Not being required to clear a dumped load, it can be built very low. Side dump wagons are made with the body mounted on trunnions and can be dumped to either side.

Dump Boxes. In addition to the various types of dump wagons, dump boxes are made by some manufacturers that can be used on the running gear of any heavy wagon. Such boxes are made in capacities of 1½ and 2 cu. yd. and weigh about 650 lb.

The Use of Dump Boxes Handled by Derricks is discussed in *Engineering and Contracting,* March 24, 1909, as follows:

There is a much greater field of usefulness for dump boxes,

than either manufacturers or contractors ordinarily suspect, as there is no reason why they should not be treated as skips and be handled by derricks, locomotive cranes, or cableways, and thus loaded and dumped.

Under the head of special wagons we have referred to the Newman wagon or car as used in Chicago. Any dump box with the proper dumping device and lever on it can be used in a similar manner.

The first dump box to be so used, to the best of our knowledge, was the Chicago Quick Dumper. On the new depot in Chicago, being built by the Chicago & Northwestern Ry., the Bates & Rogers Construction Co. being the contractors, the sand and gravel for concrete is hauled in these dump boxes. A large hop-

Fig. 10. Dump Box Made by the Baker Mfg. Co.

per is built over the mixing plant. The load is driven up to the hopper and a bridle attached to a derrick is hooked onto the box, which is raised over the hopper and dumped, after which it is returned to the gear. It is stated that only one minute is consumed in raising, dumping the box and returning it to the gear.

One of the editors of this journal timed a Newman wagon in unloading onto a large stock pile and with three men to hook on the bridle a box was unloaded and returned to the wagon or car every 1¼ min. These boxes were of 3 cu. yd. capacity, as were the Chicago Quick Dumper boxes. The bridle used is shown by the accompanying sketch, and can be made at any shop. Four pieces of steel with eyes in them to receive the hooks on the bridle must be fastened to the dump box.

In excavating cellars and similar deep pits, these boxes could be used in connection with derricks to eliminate the steep, hard pull from the pit or cellar and save the use of a snatch team, as by having several extra boxes they could be lowered by the derrick and loaded ready to be placed on the wagon when it returned with an empty box from the dump. This would mean less delay to the wagon than when loaded by other means. In loading these boxes they could be placed near abreast and material caved directly into the box. Other material could be shoveled into the box easily, as the sides are low.

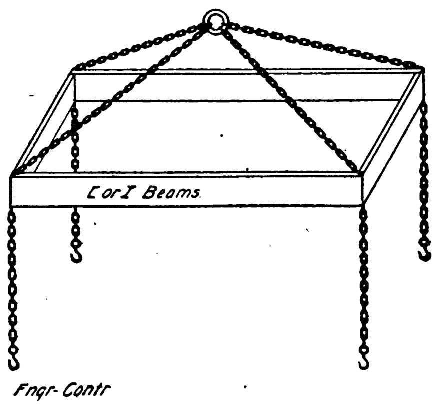

Fig. 11. Sling for Handling Dump Wagon Bodies with Derricks.

Wagon Work. There are two sizes of wagon boxes for two-horse slat-bottom wagons which are still used by contractors to a considerable extent; the small box 3 ft. wide, 9 ft. long, and 12 in. deep inside measure; and the large box with sides 4 to 6 in. deeper. The small box holds just 1 cu. yd. struck measure of loose earth, which is equivalent to about 0.8 cu. yd. measured in cut; and this is all that a team can haul over temporary or soft roads such as are encountered in railroad, reservoir work, or the like, where steep uphill pulls are common. Cole (see Gillespie) gives the average load at $\frac{2}{3}$ cu. yd. place measure, on canal work that he was in charge of. In city work, and generally in any road improvement work, where the roads are hard earth, even though there may be occasional short level pulls at each end of the haul through plowed earth, the large wagon box may be used with a load varying from 1.25 to 1.5

cu. yd. place measure; the average given in the Seventh Annual Mass. Highway Comr's Report was 1.4 cu. yd.

The average speed of a team walking steadily over hard roads with a large load, and returning at a walk empty, is about 2½ miles an hour, or 220 ft. a minute. If there are any delays in loading or unloading, a team can usually make up for such delays by trotting back at 4 or 5 miles an hour, if the roads are hard and level; so that where engineers often criticise contractors who appear to be losing money when teams are standing idle, the truth may be that the team is daily covering its 20 miles on earth roads to 25 miles on paved roads — all that can be expected anyway. Thus with a haul of 1.25 miles or more from a sand pit, it does not pay to employ shovelers to load the wagons, for each driver can load his own wagon in 52 min. with 1.33 cu. yd. of sand. The driver then gets a long rest while the team works; and by trotting the team back it will cover 20 to 25 miles in the day, unless it happens that the length of haul is such that an even number of round trips cannot be made in the 8 or 10 hr. available. Where the hauls are long, contractors should bear this last fact in mind, otherwise it may transpire that the hauling will cost some 20% more than is estimated, unless the teams can be used in plowing or otherwise for an hour or so daily, to piece out the full day. Ordinarily 15 to 30 min. are lost each morning in waiting to be loaded.

Where the hauls are 0.5 mile to 1.25 miles, one man in a sand pit to help the drivers load is all that is needed for economy.

On short hauls, under favorable conditions, the method of using extra wagons is especially to be recommended. The extra wagons are left in the pit, and one or more men load them while the team is gone; upon its return, the teamster changes from the empty to the loaded wagon in about 1.5 min. By this method both shovelers and teamsters are in a treadmill where it is easy to fix responsibility for loating, so that one foreman, or even no foreman at all, is needed for constant supervision of both gangs. This plan is good also where hauls are long and over soft roads where teams cannot trot back making up for lost time.

Where teamsters' unions exist, as in some cities, teamsters will frequently refuse to do any shoveling at all. Unless teamsters are distinctly given to understand at the start that they must shovel when ordered, and must use the kind of wagon box designated by the contractor, there may be a strike unless work is scarce.

A contractor should always be guarded in counting upon any money-saving methods wherever he finds wages are high; for high

wages generally indicate a scarcity of men, which in turn means that they will leave at the slightest provocation. While well-paid men are the most cheerful workers, a rising labor market breeds an independence among the laborers that makes it often impossible to secure a fair day's work. For example, well-paid teamsters had been hauling 1.25 cu. yd. of stone over hard earth roads and steep grades, but upon changing them to level macadam roads they refused to haul any greater loads, despite the fact that with no greater exertion a team could haul 2.5 cu. yd. Nothing but the purchase of a few teams by the contractor prevented a strike, and secured proper loading.

It is human nature apparently to "make the job last," although it is a mistaken economy in the end to do so. Dishonest teamsters will frequently pull out one of the bottom slats of their wagon, and drop the side boards so that the wagon will hold about ¼ cu. yd. less than it is supposed to. Binding chains around the body are often drawn up so tight as to pinch the top of the side boards in 6 in. The seat may not be removed in loading, leaving a large unfilled space at the front end of the wagon. An inexperienced or inefficient foreman, by not guarding against these things, will cost his employers several times his salary.

Large wagon boxes should be used wherever possible, and occasionally it may pay to have a "snatch team" (an extra team) to get a load out of the pit, or over steep hills; but a snatch team never pays where the haul is much less than ¼ mile. Where the hauls are very long, teams can travel in pairs and upon coming to a steep grade can help one another over it, each acting in turn as the snatch team for the other.

As another expedient for increasing the size of wagon loads there is the use of a three-horse team, three horses being worked abreast; thus the fixed expense of the driver is reduced by one-third, since a load fully 50% greater can be hauled by three horses than by two. Three horses cannot pull exactly together, but this is made up for by the decrease in the proportionate dead load of the wagon, and by the decrease in the coefficient of friction under greater wheel loads.

In the far West two teams are often hitched to one wagon, driven by one man; but it is not easy in the East to find "four-up" drivers.

Rule. To find the cost per cu. yd. of average earth moved in ¾-cu. yd. wagons, add the following items:

1/20 hr.'s wages of team with driver and helper plowing;
⅔ hr.'s wages of laborer shoveling;

$\frac{1}{7}$ hr.'s wages of team with driver, "lost time";
$\frac{1}{15}$ hr.'s wages of laborer dumping wagons.

Then add finally $\frac{1}{50}$ hr.'s wages of team with driver for each 100 ft. of haul. With wages of man at 30 ct. and of team with driver at 60 ct. per hr. this rule becomes: To a fixed cost of 35 ct. per cu. yd. add 1.2 ct. per cu. yd. for each 100 ft. of haul over soft earth roads with steep ascents.

If the road is hard earth and fairly level, a 1.5 cu. yd. load may be hauled; then the hauling cost, exclusive of loading, etc., is 0.6 ct. per cu. yd. per 100 ft. of haul.

The "haul" is to be measured along the road from pit to dump, one way only.

Work of Teams. A "team," as used in this book, means a pair of horses *and* their driver. Even where the word driver is omitted in speaking of the cost of team work, the wages of the driver are always included under the word "team."

A good average team is capable of traveling 20 miles in 10 hr., going 10 miles loaded and returning 10 miles empty, over fairly hard earth roads. If the team is traveling constantly over soft ground, 15 miles is a good day's work. On the other hand, if the team is traveling over good gravel or macadam roads, or paved streets, it is possible to average 25 miles per 10-hr. day. These rates include the occasional stops made for rests, etc., and include the climbing of an occasional hill.

When traveling at the rate of 2½ miles an hour, which is the ordinary walking gait of horses, the distance covered in 1 min. is 220 ft. Over good hard roads a team may trot with an empty wagon at the rate of 5 miles per hr., and thus make up for delays in loading and unloading, so as to cover the full 20 miles of daily work; but over soft ground a team should not trot.

The loads that a team can haul (in addition to the weight of the wagon) over different kinds of roads are as follows:

	Short tons	Earth cu. yd.
Very poor earth road	1.0	0.8
Poor earth road	1.25	1.0
Good hard earth road	2.0	1.6
Good clean macadam road	3.0	2.4

It is not possible to haul much greater loads over an asphalt or brick pavement than over a first-class, clean macadam. On all the kinds of roads to which the above averages apply, there may be occasional steep grades to ascend, and occasional bad spots to pass over.

The pulling power of a horse averages about one-tenth of his weight when exerted steadily for 10 hr.; that is, a 1,200-lb. horse

will exert an average pull of 120 lb. on the traces. But for a short space of time the horse can exert a pull (if he has a good foothold) equal to about four-tenths his weight, that is, four times his average all-day pull. This I have tested with teams, not only in ascending steep grades but in lifting the hammer of a horse-operated pile driver.

Where teams are traveling long distances, it is customary to have two wagons keep together, so that one team can help the other up a steep hill by acting as a "snatch team." A "snatch team," or helping team, may often be kept busy to advantage in pulling heavily loaded teams out of a pit, or onto a soft embankment, or up a steep grade. Three-horse snatch teams are frequently used. A small hoisting engine may replace a snatch team to advantage in many places. By laying channel irons for rails up a steep hill, and having a hoisting engine at the top, very heavy loads can be assisted over bad roads. In this case, a boy mounted on a pony can drag the hoisting rope back to the foot of the hill ready for the next team. Plank roads can often be built to advantage for short distances up steep grades, or over bad spots.

In the far West it is customary for three or more teams to be hitched to a train of two or more wagons; and, when a steep hill is to be ascended, to haul one wagon up at a time. This saves wages of drivers.

See Gillette's "Handbook of Cost Data" for further information on the work of teams and on the cost of detail feeding and maintaining horses and mules.

Use of Snatch Teams. When wagon teams have to go up heavy grades, as from cellar excavations and deep pits, or even on hilly roads a snatch team should be used to assist the regular team. It must be remembered in all hauling, that the heaviest grade on the road or runway, sets the limit on the size of the load, hence in most hauling and especially in hauling excavated material, the use of a snatch team means the increasing of the regular loads hauled, thus reducing the cost of transportation. Many contractors use a three-horse snatch team, and as a rule for wagon work such a team is better than two horses, but for most work, the writer prefers a four-horse snatch team, worked in two pairs. Such a team with a limited number of wagons means a larger load hauled without fatigue to the wagon team, and with a large number of wagons, it frequently happens that two wagons are loaded at about the same time, when the four-horse team can be divided into two snatch teams and the two loads are started to the dump without waste of time. Then, too, with a four-horse team, two of the horses can be used as a load

team for the plow, having only two horses on the plow regularly. Four horses may be needed on the plow to break the ground for the first plowing, but the second time the material is plowed, only two horses need be used, dispensing with the load team, which can be again joined to the snatch team.

The four-horse snatch team is well adapted to do this kind of work when three horses are used on the wagons. Most contractors work only two horses on their wagons, and the writer be-

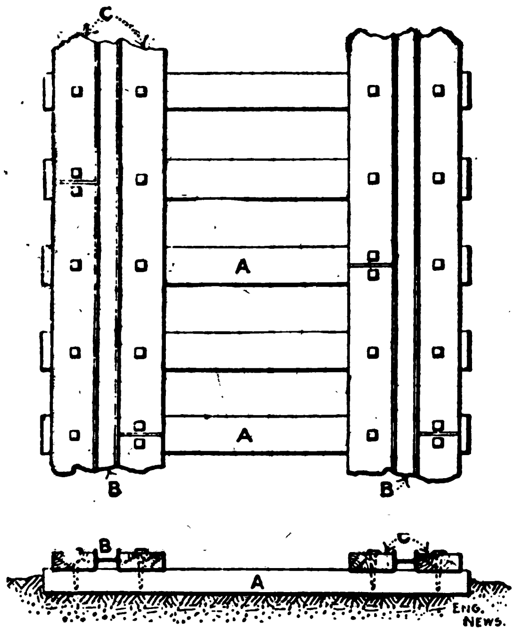

Fig. 12. Roadway for Contractor's Wagons.

lieves that this is a mistake. Most of the coal dealers in our larger cities have learned that much better work is done by a three-horse team than with two, and to-day it is a common sight to see three horses hitched to a coal wagon. The same principle applies to a contractor's hauling. In keeping the records of many thousand loads of earth hauled in bottom wagons of 1½ and 2 cu. yd. capacity, it was found that the average load hauled with two horses was 1 cu. yd., place measurement. With

three horses even with a 2 cu. yd. capacity wagon a load from 1¼ to 1½ cu. yd. could be hauled and on good roads or streets with a larger capacity wagon a larger load could be carried. The dead weight would remain nominally the same, the extra load being entirely of the material being hauled. The increased cost is the hire of an extra horse, or the expense of feeding and caring for this horse. Thus with the cost of a horse at $1.00 per day and a driver at $1.50 per day, the cost of a three-horse

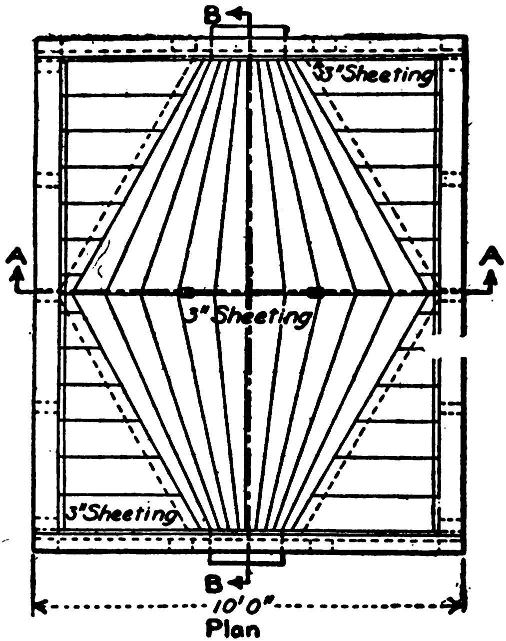

Fig. 13. Plan of Movable Hopper.

team, making an allowance of 25 ct. for the wagon, is $4.75 against $3.75 for a two-horse team. Thus with a two-horse team, hauling 10 cu. yd. per day, at a cost of 37.5 ct. per yd., a three-horse team will haul 15 cu. yd. at a cost of 31.7 ct. per cu. yd.

Special Wagon Track. A track of I beams and timbers was used on the soft fill at Grant Park, Chicago. This device was patented by Mr. W. J. Newman. It is illustrated in Fig. 12, which is taken from *Engineering News*, Aug. 24, 1905.

A Movable Hopper for Excavated Material. When excavated material must be removed rapidly in wagons because of the lack of space and facilities for storing it, and when the machinery or the work is of such character that it is not possible or economical to cease working when waiting for wagons, a storage bin

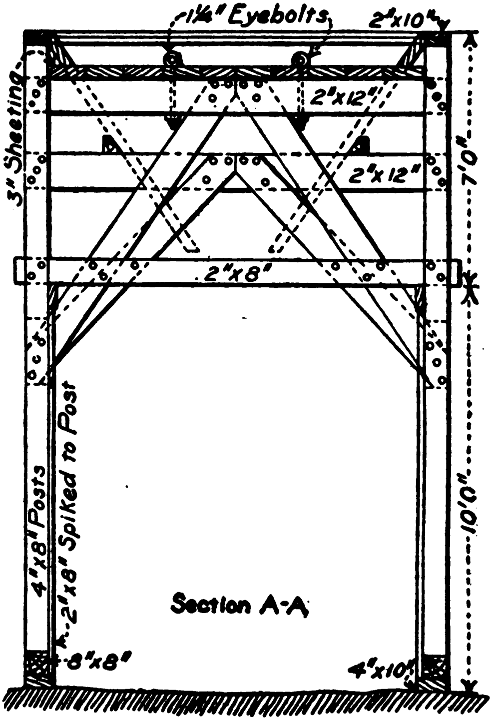

Fig. 14. Section A-A of Movable Hopper.

is advisable. Such a bin was used to store sand excavated from the foundation caissons of the New York Municipal building. It was described and illustrated by Mr. Maurice Deutsch, in the *School of Mines Quarterly*, Nov., 1910. See Figs 13–15. Another movable hopper for use with derricks is described in Chap. XII.

A Wagon Gravel Screen is illustrated in Fig. 16. This device was designed by Mr. H. S. Earle, Highway Commissioner of Michigan. In operation the bank mixture of sand and gravel is thrown across the wagon onto the screen; the sand drops through the meshes and the gravel falls into the wagon. In order to obtain a proper mixture of sand and gravel, it may be necessary to throw a certain number of shovelfuls as 1 in 3 or

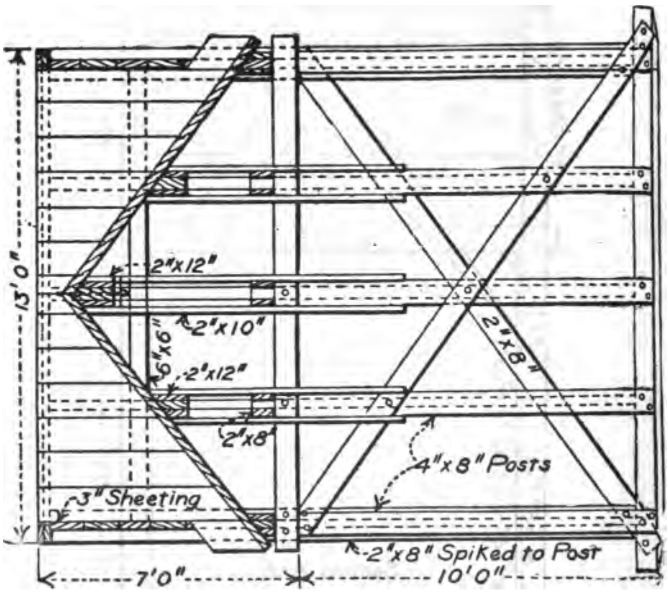

Fig. 15. Section B-B of Movable Hopper.

4, directly into the wagon. The Fig. is taken from *Engineering and Contracting*, Aug. 18, 1909.

A similar device with the addition of a target on the screen is shown in Fig. 17. This does away with having to throw material across the wagon and so keeps the material cleaner and lightens labor. The addition of the target is suggested by F. M. Hough in *Engineering News-Record*, Aug. 16, 1917.

Car Side Wagon Loaders, or "Skip Loaders." These are of interest to every owner of hauling equipment. One or two men left

in a car of sand, broken stone, etc., can charge the wagon loaders in the absence of the teams; thus no time is lost by teams waiting to be loaded at the car.

The Lee tilting wagon loader consists of a set of folding stand-

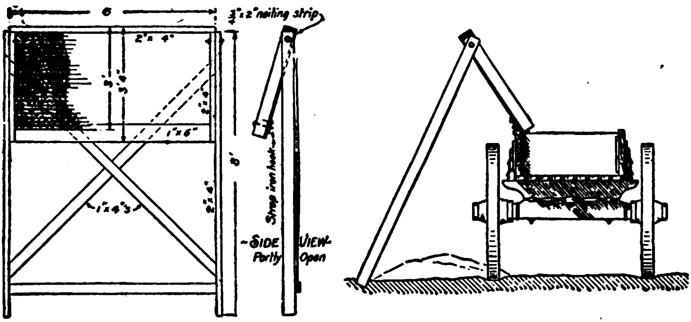

Fig. 16. Device for Screening Gravel Used with Slat Bottom Dump Wagon.

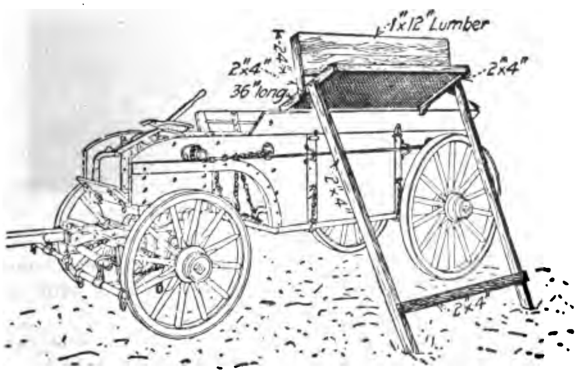

Fig. 17. Target Attachment for Gravel Screen.

ards of any length desired supporting a tilting bucket of 1.5, 2, 2.5, or 3 cu. yd. capacity. Dumping is accomplished by means of levers operated by one man on the car.

Several other makes of car side loaders are available. Most of these are designed to be attached to the side of the car to which

they doubtless impart a load that the car was never designed to sustain.

Fig. 20 shows a car side wagon loader made by the Heltzel Steel Form and Iron Co. of Warren, Ohio.

Air Jet Used to Load Wagons from a Hopper. *Engineering and Contracting*, July 15, 1908, gives the following:

In excavating the foundations for the Hudson Terminal Buildings, the material was loaded into a bucket suspended from a carriage that ran on an I-beam. The bucket was run over a hop-

Fig. 18. Lee Tilting Wagon Loader.

per, into which it discharged its load. Wagons were loaded from the hopper. The excavated material consisted of stiff wet clay and quicksand.

The water from the quicksand puddled the clay and compacted it so solidly that when the sliding door at the bottom of the hopper (see illustration) was opened to discharge the material into a waiting wagon below, the clay arched itself and it would not slip by gravity. This made it necessary to keep three to four men on a platform over the hopper to cut the material out by poking it with heavy slice bars. To load a 2-cu. yd. wagon in this manner, took about 10 min., there seldom being loaded more than 60 loads a day from one hopper.

It was accordingly decided to try an air jet to relieve these

conditions. A pipe was run from the compressor plant, and a valve placed on it convenient to the platform on which the men worked. A hose was attached to the pipe and at the end of the hose a piece of 1-in. pipe 4 or 5 ft. long was fastened. This short piece of pipe was run down into the dirt and when a wagon was ready to be loaded the air was turned on. The air caused the earth to slide and the wagon was quickly loaded.

The number of teams were at once increased and in 10 hr. from 100 to 120 wagons were now loaded at a single hopper. The

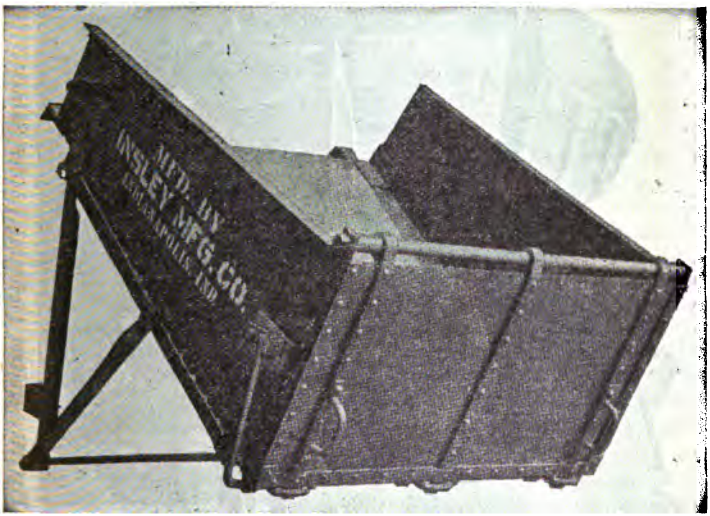

Fig. 19. Insley Carside Hopper.

largest day's work was 143 wagons loaded in a day at each hopper, or 429 at the three hoppers. At times as high as 20 wagons were loaded in an hr., being at the rate of one every 3 min.

Only one man was needed at the hopper, thus saving the labor of nine men for the three hoppers. A 2-in. pipe ran from the compressor with air at 80 lb.

Dumping Wagons with a Derrick. *Engineering News*, June 17, 1915, gives an account of an unusual method of unloading wagons in back-filling a pier of the Detroit-Superior viaduct in Cleveland, Ohio. The horses were unhitched, the loaded wagon was hooked to slings, lifted by a derrick and swung out over the

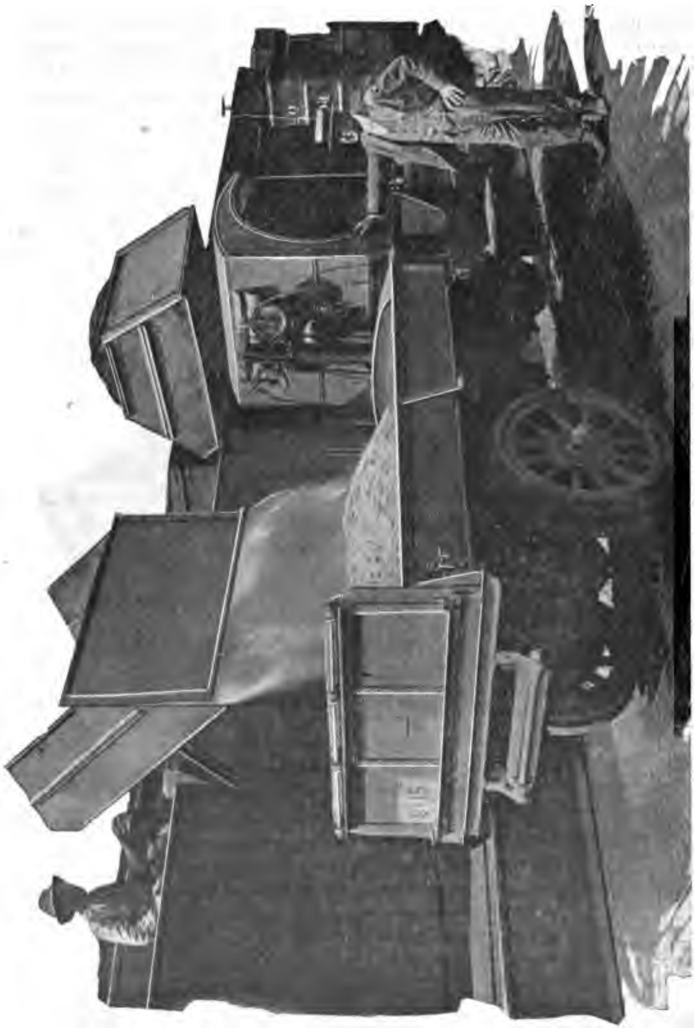

Fig. 20. Heltzel Lightning Loader Skips.

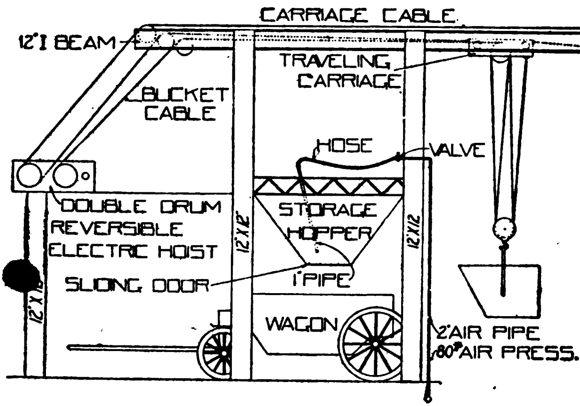

Fig. 21. Arrangement for Loading Wagons with Air Jet.

fill by a derrick. A man riding the wagon dumped it at the proper time and returned with it to land.

Miscellaneous Data on Handling Earth with Wagons. J. M. Brown, in the Transactions of the Iowa Society of Engineers, 1885, gave the following:

The earth was Iowa surface soil excavated to make a railroad embankment. Two-horse wagons holding 1.6 cu. yd. were used when hauls became 800 ft. or more; for shorter hauls wheel scrapers were used. There were five to seven shovelers to load a wagon, each man shoveling 15 to 20 cu. yd., average 17 cu. yd. per day of 10 hr. For an 800-ft. haul the force used was:

1 plow team, driver and man holding plow.
21 shovelers (3 gangs of 7 each).
9 wagons (3 gangs of 3 each).
1 foreman.

The earth moved by this force was 360 cu. yd. in 10 hr. With wages at 15 ct. an hr. for laborers and 35 ct. for team with driver, including an allowance for wear and tear on tools, the cost was:

	Per cu. yd.
Plowing	1.66 ct.
Shoveling (17 cu. yd. per man)	8.75 ct.
Foreman and dumping	1.20 ct.
Total	11.61 ct.
Hauling (including lost time) 800 ft.	9.03 ct.
Grand total	20.64 ct.

Since each team hauled only 40 cu. yd. 800 ft. in 10 hr. at a cost of 1.12 ct. per cu. yd. per 100 ft. it would appear at first sight that the wagons could not have held 1.6 cu. yd. each as stated; but when team time lost at each end of haul in waiting to load and dump is considered, we have an explanation of the high cost of 9 ct. for an 800-ft. haul. Mr. Brown adds that for every 200 ft. of added haul, one more team must be added to the force above given, which is about right, but indicates that no such load as 1.6 cu. yd. place measure was carried.

As illustrating what can be done when work is rushed and the force driven to its limiting capacity, Mr. Brown gives an example of an embankment 1.25 miles long, 10 ft. high, containing [illegible],500 cu. yd. built in 20 days. The haul was by wagons from borrow pits 1,300 ft. away. Each team made 40 trips a day, or nearly 20 miles; each man loaded 28 cu. yd. The cost was 5.46 ct. for shoveling, 6.25 ct. for team time on wagons, and 6.87 ct. for plowing, clearing, foremen, etc. Estimating backward from these data it appears that each wagon carried about 1.25 cu. yd., which is in accord with the author's experience.

The following examples of the cost of loading and hauling with wagons are taken from the author's time-books:

Cellar Excavation, No. 1. 35 men shoveling, 10 men picking and trimming, output 500 wagon loads of sandy earth in 10 hr.; each wagon averaged 1.5 cu. yd. loose measure, so that each shoveler loaded 21 cu. yd. of loose earth per day, which was probably equivalent to 16 cu. yd. in cut.

Cellar No. 2. 14 shovelers loaded 23 wagon loads in 75 min., or at the rate of one wagon load per shoveler in 45 min. Wagons held 1.5 cu. yd. loose measure, hence each shoveler averaged 20 cu. yd. loose measure in 10 hr. which is probably equivalent to 16 cu. yd. in cut. Later, 8 shovelers loaded the same wagons in from 3 to 5 min. time for each wagon load, the average of 10 loads being 4 min., which is equivalent to a rate of 27 cu. yd. loose earth shoveled per man-day or say 21 cu. yd. in place. The haul was 4,350 ft., over level pavements, except at the pit and at the dump, and the round trip took 29 min. on an average, teams jogging back part of the way at a trot, so that the average speed going and coming was 300 ft. per min. The earth was easily plowed by one team with a driver and a plow holder who loosened 300 cu. yd. a day. It will be noted that when 14 shovelers were crowded about each wagon, each shoveler loaded at the rate of a wagon load in 45 min. as compared with 32 min. when only 8 shovelers were engaged, showing the poor economy resulting from crowding the men about the wagon.

Embankment Approach to Bridge. 8 shovelers in pit, 1 man

on dump, 7 teams hauling wagons, 1 team plowing; output, 140 wagon loads of gravel per 10-hr. day, with a 3,000-ft. haul. Road level, except coming out of pit, wagon load, 1 cu. yd. loose measure, 17.5 cu. yd. loose gravel loaded per shoveler which is probably equivalent to 13 cu. yd. in place; each team traveled 22.5 miles daily; time lost in dumping was 1 min.

Dike No. 1. 3,800 cu. yd. sandy gravel measured in fill, hauled 2,000 ft., required 300 man-days and 150 team- (with driver) days, at a cost of 25.5 ct. per cu. yd.; 12.75 cu. yd. per man-day, including dump men, and 25.3 cu. yd. per team-day, including plow teams.

Dike No. 2. 6,500 cu. yd. of loam, measured in fill, moved 800 ft. on an average with wagons and No. 2 wheel-scrapers, of which 3,700 cu. yd. were hauled 1,100 ft. with wagons, and 2,800 cu. yd. were hauled 400 ft. with wheelers, 380 man-days (10 hr.) at $1.50, and 280 team-days at $3.50 were required, making the cost 24 ct. per cu. yd. as the average of both wheel-scraper and wagon work. 6 shovelers load a wagon with 1.25 cu. yd. loose measure in 3.5 min., and the man on the dump helped by the driver dump wagon in 1 min.

Dike No. 3. 5 shovelers at $1.50 per 10-hr. day, 2 teams at $3.50 and 1 man dumping and spreading, moved 540 cu. yd. coarse gravel, measured in fill, a distance of 1,600 ft., in 8.5 days; 12.75 cu. yd. per day per shoveler; 31.75 cu. yd. per day per team; 63.5 cu. yd. per day per dump man.

Loading Dump Wagons with Scrapers and "Traps." In the work described, Troy dump wagons were driven under a platform,

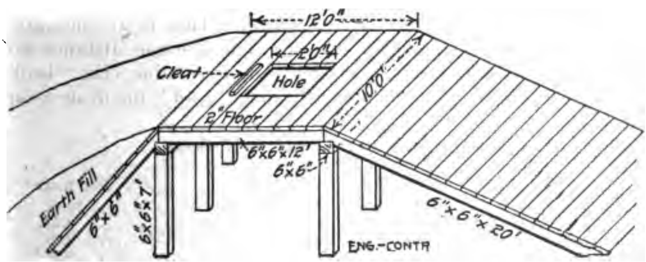

Fig. 22. Trap for Loading Wagons by Drag Scrapers.

or "trap," Fig. 22, and loaded by drag scrapers, which were dumped through a hole in the platform. The work was the excavation of a street in a Western city, and the methods and costs were noted by a representative of *Engineering-Contracting*,

Jan. 23, 1907. The street in question had a grade of about 6%, and the average cut was 2 ft. The drag scrapers were loaded and hauled down hill to the loading platform.

In the center of the platform was a hole 2 ft. square, and in front of the hole was nailed a cleat. This cleat served to catch the front edge of the drag scraper and dumped it automatically. Still it was found advisable to have a dump man on the platform to assist in dumping the scraper and to shovel any scattered dirt into the hole. On the side of the hole opposite the cleat was nailed a board which hung downward below the hole. This board served to prevent any dirt from spilling over the side of the wagon which stood under the hole.

On each end of the platform was an inclined runway. The runway on the left side was very steep, as shown in the drawing, and earth was piled up against it. The runway on the right side had a slope of 7½ ft. in 20 ft. The teams came up on the left side and descended on the right side of the platform.

Those who are used to handling drag scrapers know that a scraper can readily be hauled up a slope of 1 ft. rise in 2½ ft., which makes it unnecessary to have long runways.

The platform need not have a height of more than 7 or 7½ ft. in the clear. If the ground is very soft, it is often desirable to lay a plank roadway under the platform, for the wagons to travel over.

On this particular job there were 5 scraper teams and 1 plow team, beside the wagons. The wagon loads were very large, probably averaging 2 cu. yd. of earth measured in place, and it took 12 drag scraper loads to fill a wagon, which was done at an average rate of 5½ to 6 minutes per wagon. This is at the rate of more than 20 cu. yd. loaded per hr. The average distance from the point of loading to the platform in a direct line (the "lead") was 120 ft., which was an unusually long "lead" for drag scraper work.

The cost of loading the earth was as follows:

	Per hour
1 plow team	$0.40
1 man holding plow	0.20
5 scraper teams at $0.40	2.00
1 man loading scrapers	0.20
1 man dumping scrapers	0.20
Total, 20 cu. yd. at 15 ct.	$3.00

It will be seen that each scraper averaged 4 cu. yd. loaded per hr.

On another job where the traps were moved more frequently, the lead was about 50 ft., and 3 scraper teams loaded a wagon

with 12 scraper loads every 6 min. This was at the rate of 6.7 cu. yd. per team per hr., but it is too high an output to be counted on even with so short a haul and the easiest kind of dirt.

For a trap 10 x 12 ft. and two runways 10 ft. wide and 20 ft. long, the following is a bill of material:

	Ft. B. M.
50 planks, 2 x 12 in. x 10 ft.	1,000
5 stringers, 6 x 6 in. x 12 ft.	180
5 stringers, 6 x 6 in. x 20 ft.	300
2 caps, 6 x 6 in. x 10 ft.	60
6 posts, 6 x 6 in. x 8 ft.	144
Total	1,684

The material, at $25 per M, would cost about $42. There is practically no framing, hence the cost of erecting and taking down a platform does not exceed $2.50 per M, or $4 each time the platform is moved. Assume that a street 30 ft. wide is to be excavated to a depth of 2 ft., and that the earth is to be hauled to the platform for a distance of 130 ft. on each side of the platform. Then

$$2 \times 30 \times 270 \div 27 = 600 \text{ cu. yd.}$$

Hence 600 cu. yd. would be loaded before moving the platform, and, since it costs only $4 to move and erect the platform, we have a cost of $4 ÷ 600, or two-thirds of a ct. per cu. yd.

Frequently it is desired to load earth from a hillside. Fig. 23 shows a trap used for this purpose, where wagons were loaded

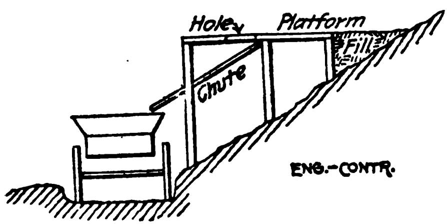

Fig. 23. Method of Loading Wagons on a Side Hill.

with sand. In this case the wagons were not driven under the platform, but were driven in front of it, and a chute from the hole in the platform served to deliver the sand into the wagon. The driver used a hoe to assist the sand in running and to "trim" the load.

It suggests itself to us that in a case like this, if a large quantity of sand or gravel were to be loaded at one spot, it might be

well to provide storage bins into which the scrapers would dump their loads. A wagon can be loaded from a bin in 1 to 1½ min.

Wagons Loaded Through a Trap by Fresno Scrapers. Contributed by W. A. Gillette to *Engineering and Contracting*, July 17, 1912.

I have taken the following data from my daily reports on an earth job running for four months and involving the moving of 206,000 cu. yd. of earth on a section of the main canal on the Yuma reclamation work. The work consisted in building a canal 84 ft. wide at the bottom, 124 ft. on the top, 10 ft. deep, top of embankment 20 ft. wide, inside slopes 2 to 1, outside slope 3 to 1. The cuts averaged about 5 ft. However, we had one hillside cut 32 ft., and much of the work was hillside cut 12 ft. to 16 ft., the deepest through cut being about 12 ft.; average haul was about 150 ft., extreme haul about 500 ft.

The material was largely sand and gravel, although some was so-called volcanic ash, a light yellow soil. Very little plowing was necessary, most of it being done with a farm plow and two mules. A small amount required four mules and some required six mules.

The cost per yd. was nearly 18 ct., including the entire cost of moving on to the work and away, which was about 2,500; brushing and clearing cost about $800.

In California, we are much in favor of the fresnos for hauls up to 200 ft., although I believe 150 ft. is their economic limit. Many contractors contend that a fresno is good up to 400 ft., and some contractors hold that a fresno will beat a wheeler at any distance. I proved to my satisfaction on this work that a wheeler, even with a drop front gate, is practically no good at all, and this in spite of my previous preference for wheelers. I do not mean to condemn the self-loading wheelers with the tongue arranged so as to take the weight off the neck of the mules because I have never used them.

I can't say that in this work the elevating grader had a fair chance, because the soil was so sandy it would hardly elevate, and most of it would not elevate at all, besides it was impossible to maintain or form a firm road for the dump wagons to travel over, though three mules were used on a 2-cu. yd. dump wagon.

Upon the economic failure of grader and wagons for hauls of 200 ft. and over, I tried wheelers up to 400-ft. haul. I soon found that it was costing as high as 28 ct. a cu. yd.; and, as the bidding price was 21¼ ct., I knew that I must try some other method. I tried the fresnos on these long hauls up to 400 ft., and that was worse, costing as high as 33 ct. a cu. yd. Loading in wagons by hand was out of the question, so finally I decided to

try loading wagons through a trap, using the fresnos to load through the trap. The cut was about 12 ft. in which there were about 30,000 cu. yd.

The first move was to make a trench wide enough to drive a wagon through and under the trap and deep enough to place the top of the trap 4 ft. above the finished canal bottom. This was done so as not to be compelled to lower the trap or raise the bottom dirt over 4 ft. to the top of the trap. The trap floor, which rested on 6 x 6-in. posts, eight on each side, was 24 ft. wide, with a hole 24 x 30 in. in the center, through which the dirt was dumped. On each side of the hole was bolted a 2 x 4-in.

Fig. 24. View of Trap for Loading Dump Wagons by Fresnos.

cleat, same length as the hole (30 in.), on which the fresno blade would strike to assist in dumping it. Much of the time the fresno crossed the trap, which was in the center of the pit, from both directions.

I used five 5-ft. fresnos, four mules each and driver, two fresno loaders, one dumper, one "two-up" plow, and five "three-up" wagons, 2 cu. yd., most of the time. On the extreme haul six wagons were used.

The fixed cost for loading was 22 mules, $22.00; five fresno drivers at $2.00, $10.00; sub-foreman, $2.50; one plow driver, $2.25; two fresno loaders at $2.00, $4.00; one dumper, $2.00; or a total of $42.75 a day. We loaded on the average one wagon about every 70 seconds with an estimated average of 1¾ cu. yd., which checked closely with the monthly estimates, or 730 cu. yd.

in eight hours, or 146 cu. yd. per fresno, which is about 5½ ct. a cu. yd. for loading by trap.

With an elevating grader we have the following itemized cost of operation: 16 mules, $16.00; elevator man, $4.00; conveyor man, $2.50; lead driver, $3.00; push driver, $2.50; or total $28.00; and, based on the same amount loaded, which would also be a fair average, 730 cu. yd. in eight hours, we have a loading cost of 4 ct. a cu. yd. Therefore where there is room for a grader, and the material is favorable, the grader has an advantage of 1½ ct. a cu. yd.

It can be seen that in sand or loose gravel, or where the lay of the ground is unfavorable, or the quantity of excavation is not sufficient to warrant the purchase of an elevating grader, the trap method is excellent.

The hauling cost was as follows: Five "three-up" wagons, 15 mules, $15.00; 5 wagon drivers at $2.00, $10.00; 1 dump man, $2.50, or $27.50 per day, or a total of $70.25 per day of 8 hr.; about 8½ ct. per cu. yd.

My average overhead cost chargeable to the trap gang was $14.00 per day, and this included superintendent, time-keeper, blacksmith and helper, camp and stable help, waterboy, camp stock working, and camp stock idle, etc. Adding this overhead item made $84.25 to move 730 cu. yd. or 11½ ct. a cu. yd.

The haul increased as the embankment was built out, so that, at the last, six wagons were used. From the trap to the beginning of the embankment was about 125 ft., and the dump extended out about 300 ft. further.

We were able to load as high as 1,000 cu. yd. many days with the five loading fresnos, or 200 cu. yd. per fresno, and on some days more. This only occurred when the dirt was bucked down hill to the trap.

I think the reason why the average output per day per fresno was only 146 cu. yd. was due to a shortage of wagons under the trap more than to inability of the loading outfit.

This low cost of moving dirt by trap and wagon brings out another interesting point, namely the amount of earth which can be moved by fresnos on short hauls. This pit was, on an average, 104 ft. wide. The extreme distance from the trap hole to end of pit was about 100 ft., showing that a fresno will move 200 cu. yd. in eight hours on a down hill pull.

Scrapers Used to Load Dump Wagons. The Tabeaud Dam near Jackson, Cal., was constructed of earth under the direction of Mr. Burr Bassell. In the beginning a steam shovel loading dump wagons was employed, but the large percentage of stone retained in the earth by this method of excavation did not meet the

requirements of the engineers, and buck scrapers of the Fresno pattern were substituted. These scrapers loaded wagons through a trap in a platform, the hole being 20 by 40 in. in size. In good material 8 scrapers filled 25 dump wagons per hour, the wagons being of 3-cu. yd. capacity. All rock of 4 in. in diameter was picked out by hand. The haul was 1/4 mile long.

Six horse-power graders leveled the loads of dumped material. Harrows and sprinklers and rollers followed. The dam was made in 6 to 8-in. layers. One roller was 5 ft. wide and weighed 5 tons, and the other weighed 8 tons and had a 40-in. face, neither roller being grooved. The loaded wagons weighed 6 tons each, and materially assisted in compacting the fill.

Mr. James C. Schuyler examined the embankment and reported that the test pits showed that there was no distinct line traceable between the layers, and no loose or dry spots, but the whole mass was solid and homogeneous.

The contract price of the work was 40 ct. per cu. yd. of embankment.

A High Cost for Wagon Work. The following is taken from *Engineering and Contracting*, Apr. 21, 1909. The work consisted of excavating earth from a barrow pit, to be used in making an embankment on a railroad. The material was sandy with but a little clay in it, yet stiff enough to be loaded by an elevating grader, but easily loosened by plowing, so that a deep furrow loosened a large mass for shoveling. A National elevating grader was used to load National dump wagons, the average lead on the material being about 2,300 ft., thus making an average haul of 2,600 ft. when using a grader, or a haul of 2,300 ft. when loading by hand, the difference being that the wagon must follow the grader to be loaded and must go to one end or the other of the pit to enter and leave it.

When the embankment was about half made, the contractor was compelled to move the grader to another section of the road, in order to hasten the construction there, and in an endeavor to continue the work in the borrow pit, he put a force of men at work there, loading some dump wagons by hand. This was done in the early part of the winter.

A plow was used to loosen the ground, but more than half the time it was employed in plowing for a gang of wheel scrapers in a nearby cut. Only the actual time of plowing is charged against the wagon work. About 12 men did the shoveling, and as the material was dumped in layers on the embankment two men were used to spread the earth. Seven wagons were used in the run.

The following wages were paid for a 10-hour day:

Foreman	$3.00
Laborers	1.50
Wagon, team and driver	5.00
Four-horse plow team	9.00

The work was continued for 17 days, the gang excavating in that time 1,293 cu. yd.

The daily cost records from the start showed a high cost, and although every effort was made to reduce these costs, and they were reduced somewhat from day to day, yet at the end of the 17 days they were still so excessive that it was decided to withdraw the gang and wait until the grader could be put back into the barrow pit.

The cost of doing the work was as follows:

Foreman, 17 days	$ 51.00
Laborers, 201 days	301.50
Wagons, 125 days	625.00
Plow, 7 days	63.00
Dump men, 36 days	54.00
Total	$1,094.50

This gave an average cost per cu. yd. of the following:

Foreman	$0.040
Loading	0.233
Hauling	0.483
Loosening	0.048
Spreading on dump	0.042
Total	$0.846

It is evident that this is a high cost. An analysis shows that each man shoveled 6.4 cu. yd. Working against a breast and casting into dump carts, a man should have loaded from 12 to 13 cu. yd. of this material in 10 hr. Each man on the dump spread 36 cu. yd. of earth in 10 hr.

Each team traveled on an average of 10 miles per day and hauled about 11 cu. yd. About 1 cu. yd. was hauled to the load, place measurement, although the wagons were of 1½ cu. yd. capacity. These figures show that the great trouble was in the gait set, both by a few men in loading and by the teams in making a fairly long haul. The loading was slow, so the teams, not being pushed, traveled at a slow pace.

As soon as the grader was put to work, the wagons were loaded quickly; they went off to the dump at a faster pace, and a toot from the traction engine pulling the grader caused them to come back from the pit at a trot. A large number of wagons were used with the grader, and there was bound to be much greater interest and enthusiasm in the work and the rate at which it was done.

This is evidenced by the cost of excavating a yard of the material with the grader, which was as follows:

Foreman	$0.01
Loading	0.04
Hauling	0.25
Spreading on dump	0.02
Total	$0.32

This shows a saving of over 52 ct. per cu. yd., and yet the grader excavated only 300 cu. yd. per day, as it frequently had to wait on the wagons to return from the dump.

Cost of Earth Excavation with Wagons During Winter Weather is given in *Engineeering and Contracting*, Feb. 5, 1908, as follows: The work was done in constructing a railroad in the month of February, when frequent snows and rain occurred, and for a number of days, the ground was freezing throughout the day. The work was started near a large body of water and a cold wind blew from over this water chilling the men and animals.

The ground was a sandy loam, and little or no loosening of the material would have been necessary if the weather had not been so cold. The material was taken from a large borrow pit and a few days' work with a plow would have loosened the 1,293 cu. yd. excavated; but, owing to the ground freezing, the plow had to be used 7 days. This alone added 4 or 5 ct. per cu. yd. to the cost.

The earth was hauled in wagons an average distance of 2,500 ft. The dump was over a marsh, and an extra man was needed on the embankment to help cast the earth ahead, so the horses could walk over the marsh. The dumpmen also had to knock some of the earth out of the wagons on account of its being frozen. For two days a third man was needed to assist in this work. This added to the cost of dumping. The wagons used were 1½ cu. yd. dump wagons, and they carried about 1 cu. yd. place measurement. Ten round trips were made a day so each wagon took 10 yd. to the dump, and the lost time and time consumed in making the trip averaged one hour for each load. This shows how the cost of hauling was increased as the teams should have traveled from 17 to 20 miles per day, instead of 10 miles.

The men shoveled 6.4 cu. yd. per day. With this kind of material from 12 to 14 cu. yd. per man-day should have been loaded, showing conclusively how the weather affected the physical exertions of the men. This small output of the men increased the supervision cost per cu. yd.

The wages paid on the job for a 10 hr. day were as follows:

Foreman	$[illegible].50
Laborers	1 50
Teams, driver and 2 horses	4.50
Plow, 2 men and 4 horses	9.00

The total cost of excavating and transporting the 1,293 cu. yd. 2,500 ft. was:

Foreman	$ 41.00
Laborers	301.50
Teams	562.50
Plowing	63.00
Dumpmen	54.00
Total	$1,023.50

This gives a cost per cu. yd. for the various items as follows:

Foreman	$0.032
Loosening	0.050
Loading	0.233
Dumping	0.041
Hauling	0.435
Total	$0.791

To illustrate how the weather affected the cost of this work, a comparison of this unit cost with some work done on the same job during the previous autumn will be made. The weather conditions were ideal. The same wages were paid. The cost per cu. yd. for the 2,500 ft. haul was:

Foreman	$0.016
Loosening	0.000
Loading	0.125
Dumping	0.019
Hauling	0.260
Total	$0.420

No plowing was done as the sandy loam was readily shoveled by the men without any loosening. The men shoveled 12 cu. yd. per day, and the teams carried 1 cu. yd. (place measurement), for a load. They traveled 17 miles per day. Two men were used on the dump, as during February.

Economical Handling of Teams with a Jerk Line. In *Engineering and Contracting*, Apr. 14, 1909, W. A. Gillette describes the method of handling teams with a jerk line, as practised in the extreme West. When three or four teams are used, as on road-grader, plow or wagon, this practice should be followed in order to do away with the unnecessary cost of extra drivers. One driver is used for one, two, three, four, five or more teams, and the driver will handle three, four or more teams with one

rein or jerk line, with as much ease as the ordinary driver handles one team. It is a comparatively simple matter to train teams to respond to a jerk line and to the shouts of "gee" and "haw."

It is customary to use a strong braided clothes line for a "jerk line." This line reaches from the "nigh" wheel animal to the "nigh" lead animal, and is fastened to the left hand side of the bit; from this main line a short piece of the line passes under the jaw to the right side of the bit, making a "Y." Fastened to the hames on the right side of the "nigh" lead is a "jockey stick" (a short piece of wood or iron) which reaches to a curb strap fastened to the bit of the "off" lead animal. A straight pull on the jerk line pulls the "jerk" line or "nigh" animal to the left, or "haw," and the "jockey stick" guides the "off" animal. A succession of jerks on the line causes the "nigh" or left lead animal instinctively to throw its head to the right, to escape from the jerking, and the "jockey stick" guides the "off" animal to the right also, or "gee."

A little patience will teach the lead team to "gee" or "haw" if the guiding words "gee" or "haw" are shouted every time the line is used. By fastening the following teams to the double trees of the team ahead, they will soon learn to follow the team ahead without being tied, and, as a matter of fact, it is not as handy in turning around if each team is fastened, as it does not permit them to cross over and out of the way of the chain while turning.

When a team has been properly trained in turning to the right or "gee," for example, the teams following the lead teams will step over on the left of the draft chain and follow it around until the chain is straight for the return trip; then each animal will cross over to his place on the right side of the chain.

Handling Excavation from a Large Cellar. According to *Engineering News*, October 8, 1914, cellar excavation for the William Penn Hotel at Pittsburgh, Pa., amounted to about 55,000 cu. yd. The depth of cut ranged from 40 to 60 ft. The excavation was made by a 1-yd. Thew steam shovel loading into 1.5-cu. yd. Koppel steel dump cars hauled by mules on narrow-gage track. These cars dumped into a 5-yd. skip at the bottom of an inclined hoist tower. This skip when at the top of the hoist tower, tripped its load into motor trucks. Three trucks and three trailers were in use, each of about 5 cu. yd. capacity. The haul to the dumping-board, at the river's edge, was about 1 mile, and some 400 trips were made in 24 hr., about 75% of the total number of trips being handled during the night on account of the clearer streets.

The dumping-board consisted of a pontoon bridge (with a planked roadway) built up of girders whose outshore end was supported by two scows. Under the bridge was a bin, into which the trucks dumped through a trap. At the end of the bridge a turntable was built up on the scows. The truck after dumping was turned on this and returned to shore running forward. The spoil was taken away on barges carrying 3-yd. boxes, filled from the bin. At the dump the boxes were lifted off by a derrick.

Fig. 25. Tipple Used for Removing Excavated Material from Wm. Penn Hotel Foundations.

The Economy of Wagon Train Haulage with Motor Trucks. The motor truck cannot always go where a team can go, and it cannot wait like a team without excessive cost for loading and unloading. In order to successfully compete with teams on earth hauling, the motor truck must have haulage conditions which make the ratio of running time to standing time large and high average speeds possible. The following, taken from *Engineering and Contracting*, Dec. 3, 1913, indicates that the greatest economy of motor truck haulage often lies in using the truck as a locomotive in connection with wagon trains.

During the past two years extensive experiments have been

made by the Troy Wagon Works Co. of Troy, Ohio, to adapt the wagons, now commonly pulled as trailers by traction engines, to

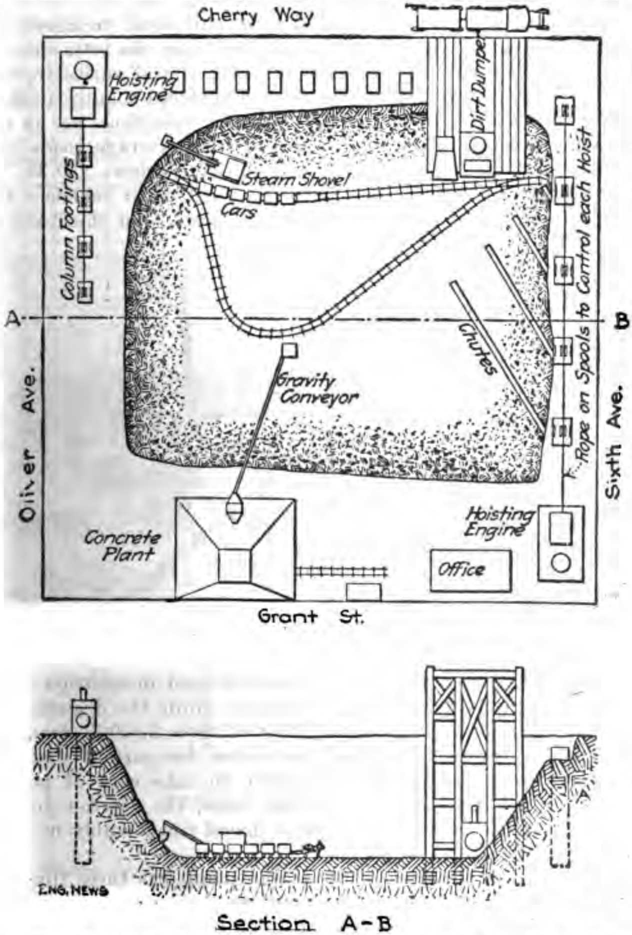

Fig. 26. Layout of Plant for Excavating for Wm. Penn Hotel.

use with motor trucks. In studying the problem of the ability of motor trucks to pull one or more trailers, the conclusion

reached was that the average truck loaded to its rated capacity, in addition to carrying its rated load, develops a drawbar pull equal to about one-half of its rated load. A team of horses will develop a maximum sustained drawbar pull equal to about one-fourth of their weight. It was estimated from the tests that the drawbar pull required to move a ton of material varies from 50 lb. on a brick street to 150 lb. on a hard surfaced country road, no grades of consequence considered. Further variations are in proportion to grades, road conditions, etc. On average roads with average grades the drawbar pull required is about 250 lb. per ton of live load moved on a properly constructed vehicle. This was another conclusion drawn from the tests. On this basis an

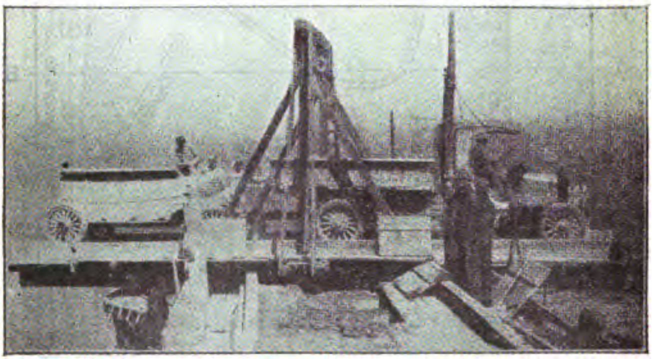

Fig. 27. Turntable Used on Wm. Penn Hotel Job.

average 3-ton truck will pull 10 tons live load in addition to the rated load on the truck proper, in other words the drawbar pull of the average 3-ton truck equals that of three 3,000-lb. teams.

Figure 28 shows "draft per ton curves for various road conditions" from actual tests. In order to take care of possible conditions not obtained in the actual tests, the per ton drawbar pull given in the paragraph above is placed considerably in excess of that shown by the tests.

Tests were made in which the trailer plant was three times the number being pulled, $\frac{1}{3}$ of the plant at the loading point, $\frac{1}{3}$ in transit and $\frac{1}{3}$ being unloaded, in order to keep the motor truck from being delayed.

Table I shows the conclusions reached from actual tests in tons delivered, comparing teams with motor alone, with motor hauling one trailer and motor hauling two trailers. In con-

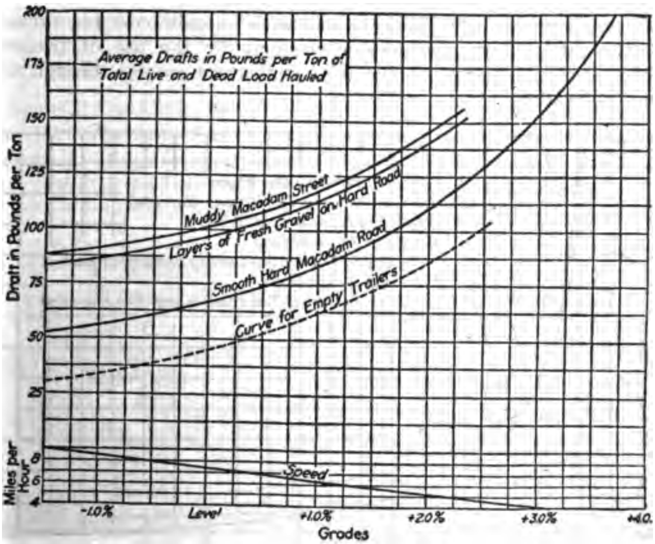

Fig. 28. Draft per Ton Curves for Various Road Conditions.

TABLE I.— DAILY TONNAGE DELIVERED

Length of haul	One team one wagon	Motor alone	Motor hauling one trailer	Motor hauling two trailers
½ mile	27	42	160	280
1 mile	18	36	140	260
2 miles	12	30	85	160
3 miles	9	21	60	110
4 miles	6	18	50	100
5 miles	6	18	35	70

TABLE II.— TON-MILE COSTS

Distance of loaded haul in miles	One team. One wagon. Cost per ton-mile	Motor alone. Cost per ton-mile	Motor hauling One trailer. Cost per ton-mile	Motor hauling Two trailers. Cost per ton-mile
½	0.444	0.480	0.210	0.258
1	0.319	0.319	0.154	0.167
2	0.256	0.240	0.143	0.118
4	0.221	0.200	0.137	0.106
6	0.214	0.186	0.135	0.104
8	0.209	0.179	0.134	0.103
10	....	0.176	0.134	0.103

nection with Fig. 29, Table II indicates ton-mile cost for various outfits and shows considerable economy by the use of trailers. The tabulated results of the tests indicate a saving through the use of trailers.

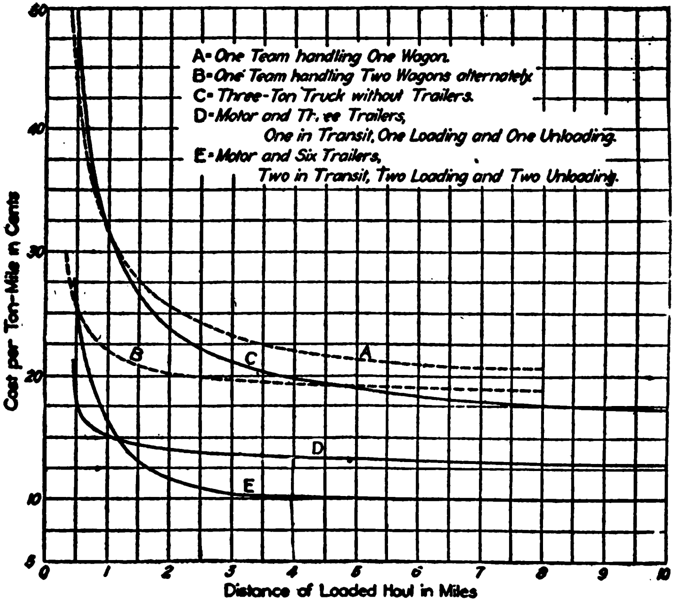

Fig. 29. Curves Showing Ton-Mile Costs for Various Outfits.

After making a study of the difficulties encountered in the manufacture and use of trailers for motor trucks the truck shown by Fig. 30 was designed, and is now placed on the market by the company making the investigations. The specifications for Troy trailers are as follows:

Length over all 14 ft. 5 in.
Width over all 7 ft. ½ in.
Wheel base is 6 ft 9 in.
Wheel height 3 ft.
Width of track from center to center of tires, 5 ft. 4½ in.
Dimensions of frame 3 ft. 5½ in. by 11 ft. 10 in.
Dimensions of tires 4 x ¾ in.
Height from ground to top of frame 2 ft. 10½ in. (No load.)
Road clearance under axles 17 in.
Clear space between steering bars 4 ft. 8 in.
Length from end to end of drawbar 14 ft. 8 in.

Springs 4 ft. by 3½ in.
Diameter of spindle, 2⅞ in.
Bower roller bearings.
Weight of chassis 3,330 lb.
Capacity 2 to 5 tons — factor of safety 25% overload.

Some of the distinguishing features of the trailer are shown in Fig. 30. The draw bar is equipped with springs which provide resiliency on grades and prevent shocks to the motor on starting and stopping the truck. Special heads are used on the draw bars to act as bumpers between trailers when operated in trains.

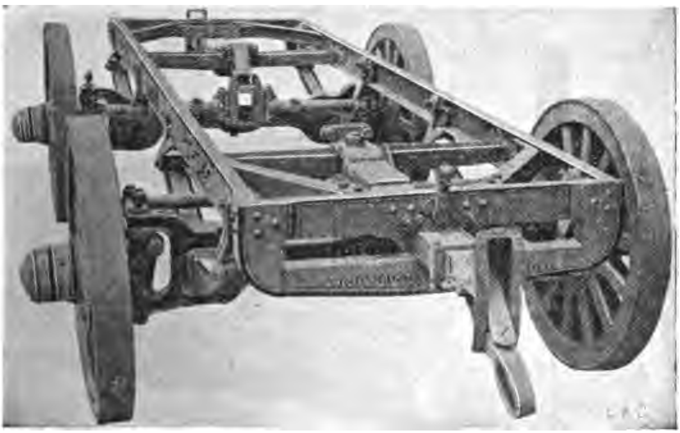

Fig. 30. End View, Showing Construction of Trailer for Motor Trucks.

Types of Tractors. The tractors now on the market can be roughly classified into three divisions. The first includes those types developed from the earlier steam farm tractor engines which were an adaption of the locomotive. They are built with steel tires and are driven either by steam or internal combustion engines. The second division includes rubber tired tractors driven by internal combustion engines which are a development of the heavier motor trucks. These machines are commonly used in connection with a trailer which is usually mounted on two steel tired wheels. The third division includes caterpillar tractors, or machines with "platform wheels."

A Traction Engine Whose Four Wheels are Driving Wheels is described in *Engineering and Contracting*, Aug. 13, 1913.

On this tractor all four wheels are of the same size and each carries one-fourth of the total weight of the machine. As no weight is carried which is not useful in producing tractive effort it is claimed that this tractor is very economical in fuel consumption, and because of the better distribution of the weight and the driving action of the forward wheels, it has shown ability to work in places where it would be impossible to use tractors of the rear wheel type.

As both axles turn in going around curves the radius of turning

Fig. 31. 35-hp. Steam Tractor Suitable for Hauling Heavy Grading Machinery.

can be very small in the 25-hp. machine, the smallest radius to the inside wheel is 8 ft.

The drive wheels are also novel in that the face is of open lattice work so that soft mud squeezes through and allows the cleats to reach a solid footing. For work in exceptionally soft mud or sand extension rims are provided.

The tractor has three speeds forward and one reverse, the three forward being 1⅗, 2¼ and 4 miles per hr. while the reverse is 2½ miles per hr. The fuel used is either gasoline, kerosene or distillate.

A Tractor and Semi-Trailer Contractors' Hauling Outfit is

described in *Engineering and Contracting*, Aug. 16, 1916. The trailer carries the load, about 70% of the weight of which

Fig. 32. Tractor with Four Drive Wheels Made by the Heer Engine Co., Portsmouth, O.

is on the rear steel-tired wheels and the tractor pulls the load. The trailer shown has a 120-cu. ft. dump body, but any special form of body required by the character of the load can be used. The trailer is quickly coupled and uncoupled and it

Fig. 33. Tractor and Semi-Trailer.

is common practice to use three trailers with one tractor, one being loaded, one being hauled and one at destination being un-

loaded. Any other of several similar combinations of trailer and more than one trailer can be effected to suit the conditions. With the combination as shown by the illustration a turn can be made without backing in a 31-ft. circle and by backing the train can be turned in a 20-ft. street. The wheel base of the tractor is only 80 in., and that of the trailer is 11 ft. 3½ in. In addition to its short wheel base the tractor has the feature of an independent spring supported from plant sub-frame. None of the load comes on the springs of this sub-frame, but on the heavy

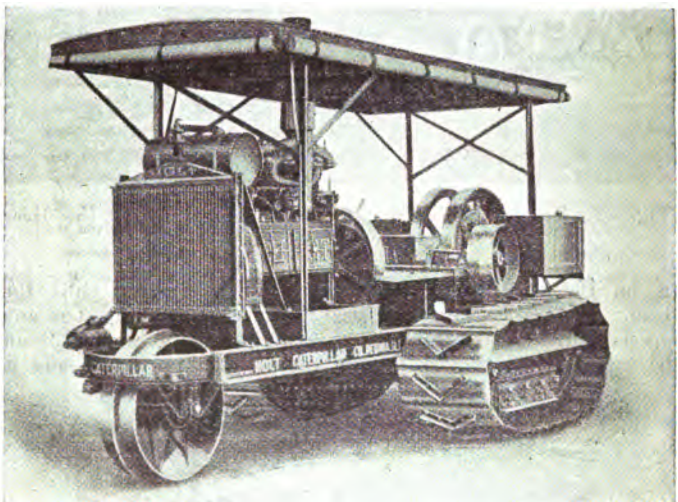

Fig. 34. Caterpillar Tractor with 30-in. Plates Attached to Platform Wheel.

springs of the main frame. There are two separate sets of springs, one set adjusted to the light constant load of the power plant, gasoline tank and driver's seat, and a second set for the tractor frame proper. The tractor hauling unit as illustrated has been tried out for a season on actual contract work and is marketed with full assurance by the builders of its efficiency. The builders are the Watson Wagon Co., Canastota, N. Y.

A "Caterpillar Tractor" for Hauling Over Soft Ground. A nine ton traction engine with its weight so carried that the load upon the ground is only 4½ lb. per sq. in., or about 650 lb.

per sq. ft. of bearing surface, is shown in Fig. 34. This machine is operated by a 45 hp. gasoline motor and has been in actual use for a number of years, chiefly in the West and South. It is called the "Holt Caterpillar Tractor."

The chief feature of the tractor is the platform wheel shown by Fig. 35. Two sprocket wheels, supported by the frame, serve to carry an endless track consisting of cast steel rails cut in short lengths and linked together with manganese steel pins. To the bases of these rails steel shoes are fastened which transmit the weight of the machine to the ground. These shoes are made in 16-, 24- and 30-in. widths so that the bearing per unit area may be suited to the condition of the ground. The widest plates (30 in.) give the bearing of 4½ lb. per sq. in., and the 16-in. plates lessen the bearing area so that the weight per sq. in. is

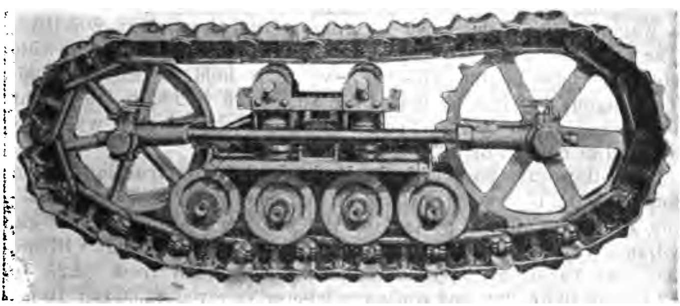

Fig. 35. Platform Wheel of Holt Caterpillar Tractor.

increased to 8 lb. For very soft ground the shoes may be provided with projecting cleats which increase their bearing surface.

The four small wheels shown by Fig. 35 support the weight of the machine upon the rails. These wheels are of semi-steel with a chilled face and run on roller bearings. It will be seen that this platform wheel arrangement is a device for laying its own track in front of the wheels and picking up the track after the wheels pass over it.

A general view of the tractor is shown by Fig. 34. The machine is 18 ft. long, over all, and weighs about 9 tons. The 45 hp. motor, when traveling at a speed of 2⅛ miles per hr., is capable of pulling a load equal to that which can be pulled by 30 horses. The machine can turn in a 30-ft. circle.

This tractor will haul trains of wagons for construction work,

road machines and elevating graders, gang plows, etc., over roads on which the ordinary tractor cannot be worked. It is particularly adapted to the hauling of plows and in this task has shown some remarkable records of earth broken up. Mr. D. H. Nelson of Pendleton, Ore., states that 960 acres were plowed in 32 days to a depth of 8 or 9 in. This was done at a cost of 47 ct. per acre, or more than 20 cu. yd. were loosened for 1 ct. A machine owned by J. J. Hicky of Thornton, Cal., has plowed 3,000 acres in two seasons and the repair costs have amounted to $425.

The tractor described is manufactured by the Holt Manufacturing Co., and the Holt Caterpillar Co., whose New York offices are at 50 Church St.

Caterpillar Wheels. When wagons are hauled over soft ground by a tractor, not only the traction engine, but the wagons themselves may be fitted with "caterpillar" traction wheels. Such a wagon train is described in *Engineering News*, May 20, 1915. The traction engine is of the three-wheel type, with a single wide steering-wheel having ribs to give it a hold in soft ground. The wagons are 11.5 by 9 ft. over all, and 5 ft. 8¼ in. in height to the top of the body. The carrying capacity of each wagon is about 180 cu. ft., or 10 tons.

Miscellaneous Costs of Excavation in Construction of a Smelter. E. H. Jones, *Bulletin of the American Institute of Mining Engineers*, July, 1914 gives the average cost of 131,371 cu. yd. of excavation in the construction of a large smelter at Clifton, Ariz. as 79 ct. a cu. yd. Teamsters were paid from $2.25 to $2.70 per 10-hr. day and ordinary laborer received $2.00 per 10-hr. day.

Excavation was divided into nine classes according to haul and tools used.

Class 1. Shallow excavation with picks, shovels, wheelbarrow and slips. Hauls were less than 100 ft.

A trestle approach was excavated through cemented sand and gravel permeated with calcine. All the work was done by hand using picks and shovels. The excavated material was cast to the side of the holes and in some cases it was handled three times. There were 277 cu. yd. of earth moved at a cost of $1.30 per cu. yd.

A track scale foundation was excavated, being a long narrow cut through earth fill and sand and gravel. It was taken out with picks and shovels and transported 200 ft. with slips or drag scrapers. There were 118 cu. yd. of excavation at $0.92 per cu. yd.

A trestle foundation for a siding was excavated through tight red soil filled with large stones. The excavation consisted of a

shallow rectangular cut. It was picked, shoveled, and wheeled in barrows 50 ft. There were 589 cu. yd. of excavation at $0.93 per cu. yd.

A building foundation was excavated and the necessary back fill tamped in 5-in. layers in the low part where the basement concrete floor was to be cast. It was done with picks, shovels, and wheelbarrows in earth, sand and gravel. There were 322 cu. yd. excavated at $0.89 per cu. yd.

An air pipe line trench with a large slice through red clay and boulders into sand and gravel tightened with calcine. It was shaken up with powder, plowed, transported to a trap in narrow gage side-dump cars and conveyed 1,000 to 2,000 ft. by a narrow gaged locomotive. There were 331 cu. yd. of excavation at 68 ct.

A floor foundation for a warehouse was excavated, which entailed cutting down the floor of the warehouse 6 to 8 in. and back filling in places. There were 66 cu. yd. of excavation at $1.96.

Class 2. This type covers excavations made with picks, shovels, slips and carts. The haul was over 100 ft. in every case.

A track scale foundation was excavated in tight sand and gravel. It was done with pick and shovel handled in the cars and hauled 500 ft. There were 388 cu. yd. excavated at $0.90.

A wall foundation was excavated, being a long narrow cut through earth fill and sand and gravel. It was taken out with picks and shovels and transported 200 ft. with slips. There were 60 cu. yd. excavated at $1.29.

A boiler foundation was excavated. This work was digging shallow trenches for small foundations through red clay and small boulders. The ground was picked, shoveled and hauled 600 ft. There were 120 cu. yd. excavated at $1.65.

A storage tank foundation was excavated consisting of making a top slice to prepare the site for foundations of two 500,000 gal. oil tanks. It was done with plows, picks, slips and shovels and was hauled 150 ft. There were 544 cu. yd. excavated at $0.56.

Class 3. This class covers excavations made with powder, picks, shovels and wheelbarrows. The haul was less than 100 ft. There were 4,211 cu. yd. of excavation of this type moved at $0.84 per cu. yd.

Conglomerate rock was graded off in preparing the site for a well. Large blasts of dynamite were used. There were 2,600 cu. yd. excavated at $0.80.

Wagon roads were made for construction purposes. There were 951 cu. yd. of excavation at $0.97.

Water supply tank foundations were graded, a 3-ft. slice being removed with powder, picks, shovels and wheelbarrows. There were 116 cu. yd. of earth moved at $1.24.

Class 4. This class covers excavation made with powder, picks, shovels, fresnos and carts. The haul was over 100 ft. There were 15,541 cu. yd. of this type of excavation moved at $1.00 per cu. yd.

Bin foundations were excavated through earth, sand and gravel bonded with calcine. The excavations consisted of long, narrow, deep cuts. Powder and plows were used to loosen the ground. Part of the work was done with slips and fresnos; another part by picks, shovels and wagons. The average haul was 600 ft. There were 12,319 cu. yd. excavated at $0.99.

Building foundations were excavated to grade with fresnos hauling the earth 450 ft. Deep cuts were then made through red clay and boulders to gravel to provide for steel foundations. There were 1,216 cu. yd. excavated at $1.27.

Retaining wall foundations were excavated through 2 ft. of clay followed by sand and gravel and boulders with calcine. The ground was partly blasted, all picked, shoveled into wagons and hauled 600 ft. There were 306 cu. yd. excavated at $0.93.

Another retaining wall foundation was a deep cut through sand and gravel made with picks and shovels. The material was hauled 300 ft. There were 404 cu. yd. excavated at $1.00.

Class 5. This class includes excavation with plows, slips, fresnos and in some cases, powder. The haul was less than 100 ft. There were 11,210 cu. yd. of excavation of this type moved at $0.93 per cu. yd.

Building foundation excavation consisted of a 6-ft. slice to get the proper grade for the site, together with piers and small wall excavation. Earth was plowed and moved 400 ft. in fresnos. There were 1,458 cu. yd. of excavation at $0.82.

Another building excavation was a cut 55 by 280 by 10 ft. for the basement, machine foundation and piers of a power house. The material was red clay and boulders on top, with sand and gravel beneath which was saved for concrete material. Powder was used, followed by plowing, picks, shovels, fresnos and carts. The material was hauled 450 ft. There were 7,313 cu. yd. excavated at $1.07.

Railroad grade was formed along each side of an oil sump. There were 2,439 cu. yd. excavated at $0.61.

Class 6. This class includes excavation with plows, slips, fresnos and in some cases powder. The haul was over 100 ft. There were 13,160 cu. yd. of excavation of this type moved at $0.89 per cu. yd.

Chimney foundation excavation consisted of a deep hexagonal cut through clay, calcine and sand and gravel containing big boulders. The material was loosened with picks, moved in

fresnos, dumped through a trap into carts and hauled 2,700 ft. There were 597 cu. yd. excavated at $0.61.

Building foundations were excavated through red clay and boulders into sand and gravel tightened with calcine. The earth was a large slice similar to sidehill excavation. It was shaken up with powder, plowed, fresnoed through a trap into side dump cars and hauled 1,000 to 2,000 ft. by a narrow-gage locomotive. There were 6,330 cu. yd. excavated at $0.91.

Boiler foundations were excavated consisting of shallow trenches for small walls through red clay and boulders. The earth was picked, shoveled and hauled 600 ft. There were 97 cu. yd. excavated at $0.76.

Class 7. These were miscellaneous jobs where a variety of methods were used. There were 58,685 cu. yd. of excavation of this type moved at $0.64 per cu. yd.

Yard track excavation consisted of excavation and borrow including rock (Gila conglomerate), hard clay soil filled with limestone and light loam. Plows, powder, picks, shovels, slips and fresnos were used. The work was not carried on continuously, but the unit cost represents fairly the average cost of shallow excavation. There were 55,405 cu. yd. moved at $0.64.

Water pipe trenches were about 3 ft. deep through red clay and boulders. A 16-in. wood stave pipe 1,104 ft. long was laid and backfilled. There were 2,406 cu. yd. excavated at $0.62.

Steam pipe trenches were excavated through red clay. There were 228 cu. yd. excavated at $0.73.

Class 8. This class of excavation was done with picks, shovels, wheelbarrows and carts. Excavations for piers 7 by 7 ft. in size were made from 16 to 25 ft. deep in gravel. The dirt was easily dug but had to be handled from the lower half of the holes with windlasses. It was carted away at the top a distance of 225 ft. There were 1,428 cu. yd. excavated at $1.64 per cu. yd.

Class 9. This includes backfilling and tamping in 4 to 5 in. layers. There were 7,195 cu. yd. of excavation of this type moved at a cost of $0.66. Adobe was backfilled behind a long retaining wall, wetted and tamped in 5-in. layers. The dirt was wheeled 60 ft. to place. There were 972 cu. yd. moved at $0.56.

Red clay was plowed, hauled in wagons, dumped, shoveled into a derrick box, lifted by a locomotive crane and dumped near the place it was to be used. It was then distributed with wheelbarrows and tamped in 4-in. layers. There were 3,679 cu. yd. moved at $0.75.

Sand and gravel was backfilled behind a wall 300 ft. long. The material lay 8 to 10 ft. from the wall. There were 129 cu. yd. moved at $0.53.

Analysis of Hauling Costs. In a paper read by Prof. T. R. Agg at the Good-Roads Congress at Chicago, Dec. 15, 1914, a method of analyzing the cost of hauling materials for construction work was given.

The following are the principal factors affecting the problem: (1) length of haul; (2) rate of travel; (3) time lost while loading at cars and unloading at the work; (4) time lost in travel on account of bad roads; (5) capacity of the outfit per trip; (6) cost of operation.

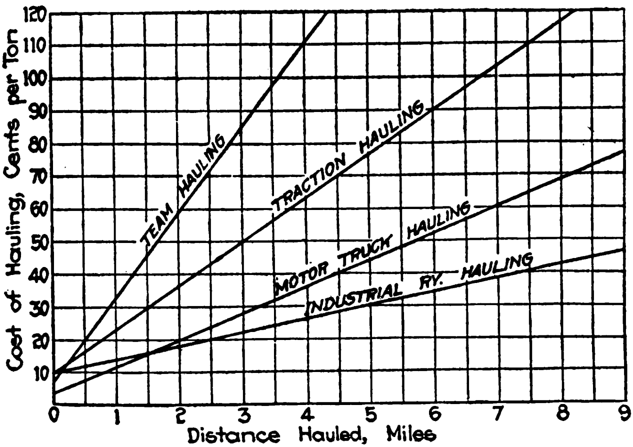

Fig. 36. Diagram for Analyzing the Cost of Different Methods of Hauling Road Material.

The following rates of speed have been assumed.

For teams 2.5 miles per hour.
For traction outfit, 3 miles per hour.
For motor trucks and industrial railways, 10 miles per hour.

The amount of time lost at cars depends upon the method of loading. This time should be eliminated as far as possible, especially on short hauls. The average loss of time per trip in loading and unloading has been assumed as follows:

With team hauling, 18 min.
With motor trucks (loaded from bins or hoppers), 6 min.
Traction outfits and industrial railways, 30 min.

The time lost due to the condition of the road varies with the season, the locality and the kind of road. It is greatest with the traction outfit, is about the same for team and motor-truck haul-

ing, and is a negligible factor for the industrial railway (with locomotive).

The following capacities have been assumed:

For team hauling with wagons, 2 ton.
Motor truck, 5 tons.
Traction outfits, 15 ton.
Industrial railway trains, 20 tons.

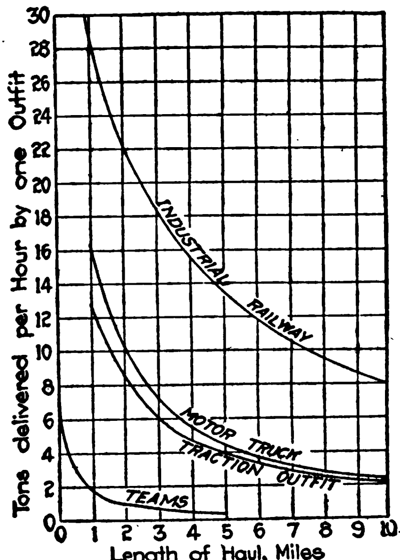

Fig. 37. Capacity Diagram for Assumed Conditions.

The cost of operation of each of these outfits will vary principally with the skill of the superintendent and the operator, the kind of weather, and the nature of the road. It should comprise the following items:

Interest on investment.
Depreciation on outfit.
Maintenance of outfit.
Fuel, oil, supplies and labor cost.

The following values have been assumed:

For team (and driver), per hour, 50 ct.
For motor truck, per hour, \$2.00.
For traction outfit, per hour, \$3.00.
For industrial railway per hour, \$4.00.
The cost per ton may be obtained through the following equation:

$$C = \frac{rd}{us} + \frac{Tr}{u}$$

Where C = cost per ton for a length of haul ($= \frac{1}{2}d$).
d = distance in miles per round trip.
u = tons hauled for trip.
s = speed of vehicle, mi. per hr.
T = time lost in loading and unloading.
r = cost of operation in dollars per hour.

Fig. 36 shows a curve drawn on the assumptions noted. Fig. 37 is a diagram of capacities based on the same assumptions.

Methods and Cost of Hauling. A formula for figuring transportation costs with animals, that has been worked up by R. T. Dana, of the Construction Service Co., is here given.

Speed of horses. A team (2 horses) can travel 10 miles loaded and return 10 miles empty, or a total of 20 miles, in 10 hr. over fairly good earth roads; 15 miles over poor ground; and 25 miles over good macadam, gravel, or paved streets. This gives the following rates of travelling in ft. per min.: Poor roads, 132 ft. per min.; fair earth roads, 176 ft. per min.; best roads, 220 ft. per min. A speed of 220 ft. per min., or 2.5 miles per hr., may be expected as an average rate of teams when actually walking not including time due to delays and rests. Cost tables figured by these formulas for wagons and carts are given.

FORMULA FOR TRANSPORTATION

(R. T. Dana)

C = The total expense per day in ct.
w = The net load for the average trip in lb.
S = The speed (average) when loaded, in ft. per min.
KS = The speed (average) when returning, in ft. per min.
D = The length of haul in ft.
l = The time lost in turning, resting, and wasted for an average round trip, in min.
R_T = The total cost in ct. per ton for transportation.
W = The number of minutes in the working day.
L = A constant representing the cost of loading.

The following facts are deducible algebraically.

$$\frac{D}{S} = \text{Time for a loaded trip in minutes.}$$

$$\frac{D}{KS} = \text{Time for the empty haul.}$$

$$l + \frac{D}{KS} = \text{Actual time not occupied in transporting material in minutes.}$$

$$\frac{D}{S\left(1 + \frac{1}{K}\right)} + l = \text{Average time for one round trip in minutes.}$$

$$\frac{W}{\frac{D}{S}\left(1+\frac{1}{K}\right)+1} = \text{Average number of trips per day. This value must be an integral quantity for the average work of any one day.}$$

$$\frac{Ww}{\frac{D}{S}\left(1+\frac{1}{K}\right)+1} = \text{Average total amount transported per day.}$$

$$R = C\,\frac{\frac{D}{S}\left(1+\frac{1}{K}\right)+1}{Ww} = \text{Cost of transportation per lb.}$$

$$R = C\,\frac{\frac{D}{S}\left(1+\frac{1}{K}\right)+1}{Ww} + L = \text{Cost of picking, loading and transporting.}$$

Value of Factors in Transportation in Formula for 2-Horse Wagon Work: C (= total expense per day) on average work is given in Tables I and II.

TABLE I.—VALUE OF SERVICES OF AVERAGE HORSE

Depreciation per annum	$ 22.50
Feed, 10 working months @ $15.50	155.00
Feed, 2 idle months @ $5.00	10.00
Straw, 12 months @ $1.00	12.00
Shoes and medicine, 10 working months	20.00
Shoes and medicine, 2 idle months	1.00
Interest on $150 @ 6%	9.00
Stable man at $45 per month for 15 horses	36.00
Stable rent and miscellaneous	15.00
Total per annum	$280.50
Cost per working day (187.5 days)	$1.50

TABLE II.—COST OF TEAM AND DRIVER PER DAY

2 horses @ $1.50	$3.000
Depreciation on wagon (value $110)	0.124
Interest	0.044
Repairs	0.150
Miscellaneous (including harness)	0.182
Driver	1.500
Total per day per team	$5.00

w = (the total load) varies widely according to the grade, state of the road, and other conditions. It averages about 1.4 cu. yd. place measure for earth.

s = 200; ks = 240 ft. per min.

l varies greatly mainly according to the method of loading and the quality of the superintendence. When the material is loaded by hand it takes from 5 to 20 min. (average 8 or 9 min.) to load

a wagon, depending on the number of loaders. Dumping with bottom dump wagons should consume no time, but usually takes about 0.33 min. On most excavation work there is considerable time spent waiting to get into position for loading due to the unequal spacing of the teams. The total time not occupied in transportation ranges from 5 to 30 min., averaging about 10 min. per trip.

L for wagon work equals about 15 ct.

The formula then becomes.

$$R = 0.00382\ D - 4.1666 - 15, \text{ when } w = 2.00$$
$$R = 0.00546\ D - 5.9523 - 15, \text{ when } w = 1.4$$
$$R = 0.00955\ D - 10.4167 - 15, \text{ when } w = 0.8$$

TABLE III.—COST OF HAULING WITH 2-HORSE WAGON IN CENTS PER CUBIC YARD

(Wages of man, 15 ct. per hr.; horse, 15 ct. per hr.)

Length of haul ft.	50	100	150	200	250	500	1,000	1,500	5,280
Load, 2 cu. yd.	19.4	19.5	19.7	19.9	20.1	21.1	23.0	14.9	39.4
Load, 1.4 cu. yd.	21.2	21.5	21.8	22.0	22.3	23.7	26.4	29.2	49.8
Load, 0.8 cu. yd.	25.9	26.4	26.9	27.3	27.8	30.2	35.0	39.7	75.8

Capacity of Carts. One-horse, two-wheeled dump carts hold from 0.3 to 0.6 cu. yd. Over poor roads loads of earth seldom exceed 0.4 cu. yd. (place measure), but loads of 0.48 cu. yd. of gravel and 0.52 cu. yd. of sand are common while 0.59 cu. yd. and 0.63 cu. yd. may be carried easily. Double carts and wagons hold about twice as much as single carts, the quantity of earth carried being limited by the condition of the road.

With hauls of 300 ft. or less one driver can attend to two carts, by leading one to the dump while the other is being loaded; on long hauls, where the relative positions of pit and dump are fairly constant, the horses may be quickly trained to travel without a driver.

Cost by Carts. The factors in the transportation formula on average work are as follows:

$E = \$3.25$ (= 1 horse, $1.50 — depreciation, 0.083, interest, 0.02, repairs, $0.10, on $50 cost + harness and miscellaneous, $0.047,+ driver, $1.50).
$w = 0.6$, 0.4 or 0.3.
$s = 200$.
$ks = 240$.
$l = 4$ (3 for loading and 1 for dumping).
$W = 600$
$L = 15$ (cost of picking and loading).

The formula then becomes:

$$R = .00827\ D - 3.6111 + 15, \text{ when } w = 0.6$$
$$R = .01241\ D - 5.4167 + 15, \text{ when } w = 0.4$$
$$R = .01644\ D - 7.2222 + 15, \text{ when } w = 0.3$$

TABLE IV.— COST OF LOADING AND HAULING WITH 1-HORSE CART IN CENTS PER CU. YD.

(Wages of man, 15 ct. per hr.; horse, 15 ct. per hr.)

Length of haul ft.	25	50	100	150	200	250	500	1,000	1,500
Load, 0.6 cu. yd.	18.9	19.0	19.4	19.9	20.3	20.7	22.7	26.9	31.0
Load, 0.4 cu. yd.	20.7	21.0	21.7	22.3	22.9	23.5	26.6	32.8	39.0
Load, 0.3 cu. yd.	22.6	23.1	23.9	24.7	25.5	26.4	30.5	38.8	41.0

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CHAPTER VIII

METHODS AND COST WITH ELEVATING GRADERS AND WAGON LOADERS

An elevating grader consists of a plow casting a furrow upon a transversely traveling belt that elevates the earth, dumping it into wagons traveling alongside the grader.

In sand or gravel, where a plow will not turn a good furrow, the elevating grader cannot be used. There must be few boulders or roots to stop the plow of the machine; and there must be considerable room in which to turn the machine, and manœuver the teams going and coming. The machine is not well adapted to loading wagons on road work, but is especially suitable for reservoir work and the like.

The machine is used in prairie soils for digging ditches and carting the material directly into the road, but the material must afterward be leveled with a leveling scraper or road machine; and it would seem better practice to use the road scraper entirely for this class of grading without resort to the elevating grader at all.

In moving fairly soft clayey loam of the Chicago Drainage Canal with New Era grader and wagons, haul being 500 ft., the output was: Section I, September, 485 cu. yd. per 10-hr. day; Section K, August, 490; September, 515 cu. yd. per 10-hr. day. The plant consisted of 7 wagons, 28 horses and 17 men and one grader. With wages at 30 ct. per hr. for men and 15 ct. per hr. for a horse, we have a labor cost of $9.30 per hr. With an output of 50 cu. yd. per hr., the labor cost would be 18.6 ct. per cu. yd.

An elevating grader costs $1,400, and the seven dump wagons cost $1,800. This $3,200 plant we may assume can be rented some years, and some it cannot, so that its owner may perhaps estimate using it or renting it for 64 working days annually; with annual interest, repairs and depreciation at 20%, we have $640 a year, or $10 as the charge to be made for each working day. The cost of plant, therefore, adds about 2 ct. to each cu. yd. moved.

Where the work is of great magnitude, the cost of the plant may be divided by the total number of cu. yd. to be moved with it, which is a common way of estimating work upon the part of contractors. Summing up we may put the cost of moving earth with elevating graders thus, assuming an output of 500 cu. yd moved 500 ft. in 10 hr.:

	Ct. per cu. yd.
10 horses and 5 men on grades	6.0
18 horses and 6 men on 6 wagons	9.0
5 men on the dump and grubbing	3.0
Total labor	18.0
Plant rental	2.0
Total	20.0

Due to the fact that room must be had in which to move the grader and the string of teams on the wagons, we are not safe in figuring on a haul of less than 500 ft. no matter how short the "lead" actually may be.

Using three-horse dump wagons holding 1.25 cu. yd. place measure for hauling, an elevating grader with five teams and five drivers and helpers, and one man on the dump for every 100 cu. yd. delivered, we have:

Rule. To find the labor cost per cubic yard of average earth loaded with an elevating grader and hauled with three-horse dump wagons, add together the following items:
$\frac{1}{10}$-hr.'s wages of a 2-horse team with driver on the grader;
$\frac{1}{6}$-hr.'s wages of a 3-horse team with driver for "lost time";
$\frac{1}{10}$-hr.'s wages of man dumping;
then add $\frac{1}{80}$-hr.'s wages of a 3-horse team with driver for each 100 ft. of haul over 500 ft. With wages at 30 ct. for labor, 15 ct. for a horse, this rule becomes: To a fixed cost of 17.5 ct. per cu. yd. for all hauls under 500 ft. (corresponding to a "lead" of 200 ft.), add 1 ct. for each additional 100-ft. haul. To this add 2 ct. for plant rental.

Traction Engine and Grader. The writer kept the following records of cost, using a 25 HP. traction engine for hauling an elevating grader. Soil was easily plowed earth taken from "pits" alongside the railroad fill. The crew was one engineman, two men operating the elevating grader, one team on water tank, nine two-horse dump wagons, four men on dump spreading, one water boy and one foreman. The "lead" was only 100 ft. The grader traveled 600 ft., in which distance it loaded 15 wagons and then turned around, the turn taking 1 to 2 min. Each wagon had about 1 cu. yd. of loose earth, equivalent to about 0.7 cu. yd. in "cut," and 700 wagons were loaded per 10-hr. day. It took about 15 sec. to load a wagon (the grader traveling about 150 ft. per min.), then the grader stopped for 15 sec. until the next wagon came up into place. It required a width of about 50 ft. in which to turn the grader and engine. Six three-horse wagons would have served much better than the nine two-horse wagons used.

The traction engine uses about 0.7 ton of coal per day of 10

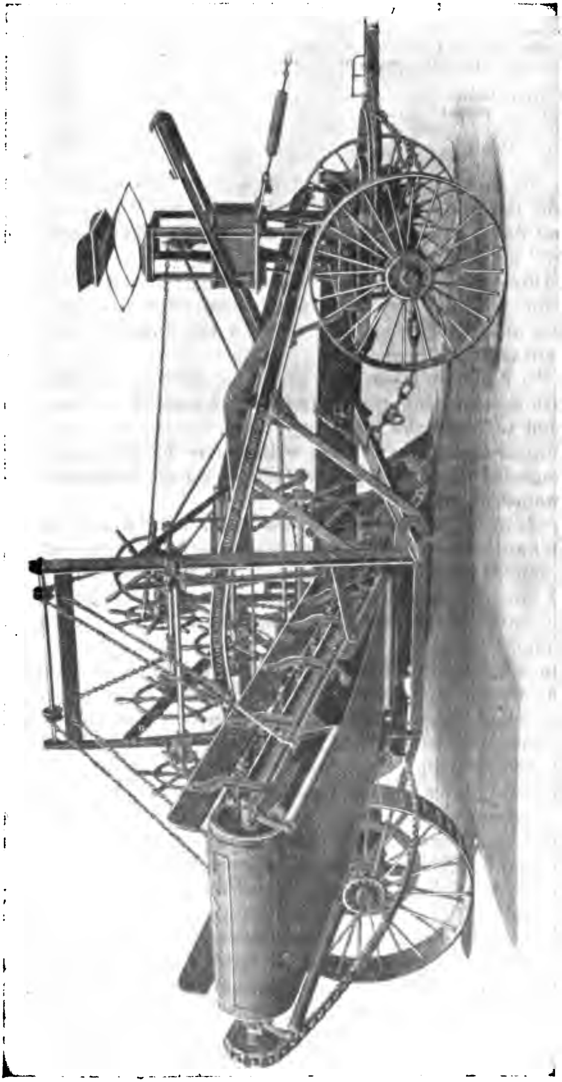

Fig. 1. Improved Steel New Era Grader.
(Right Hand Side)

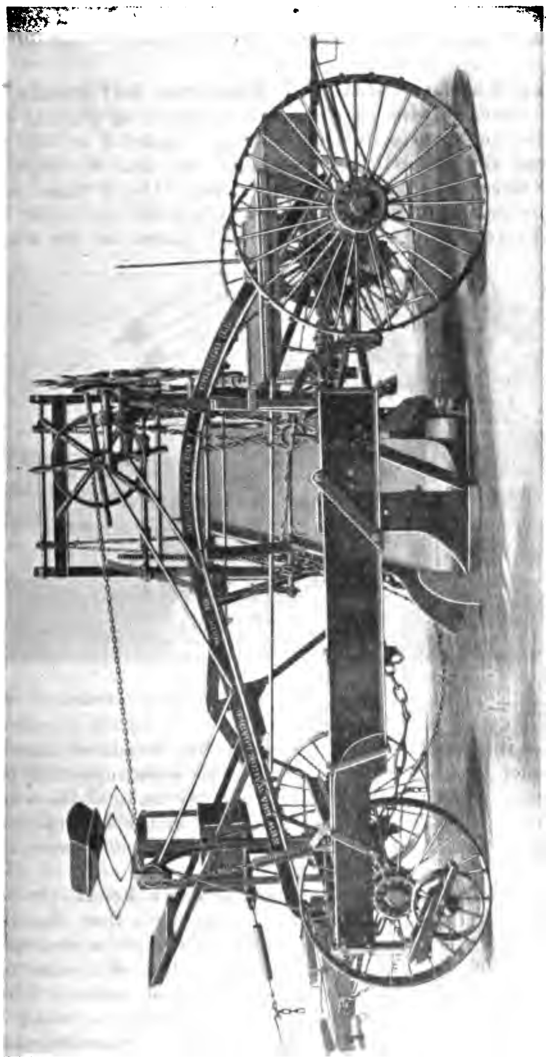

Fig. 2. Improved Steel New Era Grader.
(Left Hand Side)

hr. Annual interest, repairs and depreciation may be estimated at 20% of the first cost. Ordinarily a tractor can not be counted upon to work more than about 100 days each year, year in and year out.

Widening Wheels of Grader for Work Over Soft Ground. A method of increasing the bearing areas of elevating graders that should be of interest to dirt movers was employed in the construction of the Sieberling Division of the Lincoln Highway across the Great Salt Lake Desert of Utah. Heavy rains made the soil so soft that it was difficult to operate the road machinery. Extra bearings were accordingly placed on the wheels

Fig. 3. Paddles on Wheels of Elevating Grader.

of the elevating graders and the caterpillar treads of tractors. On the graders the outer ends of the planks were supported by a ring. Diagonal brace rods extended from the hubs of the wheels to the planks. The arrangement is shown in the accompanying illustration, which is taken from *Engineering and Contracting*, March 19, 1919.

Method of Using Elevating Graders on Earth Roads. In road building, an elevating grader will take the earth from the ditch and deposit it directly into the grade where wanted, in one operation. Fig. 4 taken from the catalog of the Russell Grader Mfg. Co. of Minneapolis, Minn., shows the method of building a road grade. The figures and letters indicate the order in which the furrows are plowed up in the ditch and the respective points of delivery in the grade by use of 16-ft. carrier. For instance,

furrow No. 1 indicates the first one handled and is delivered about four ft. across the center of the road to the point indicated by the Fig. 1. Furrow A is taken on the opposite side of the road and delivered to a similar position about four ft. across the center. (This method is called crossfiring.) Each respective furrow is taken out of the ditch in the order numbered, the fifth and sixth furrows doubling up in the center and the first plowing in itself leaves a substantial grade with ten furrows or rounds. The second plowing takes out furrows 11 to 17 respectively,

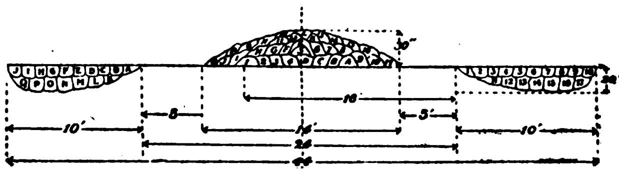

Fig. 4. Method of Building a Dirt Road by "Crossfiring" with an Elevating Grader.

bringing the grade up to a height of approximately 30 in. With a berm as shown it will permit driving on the side until the grade is ready for travel. As the grade is dressed down and as the roadbed becomes firmer the earth will work out toward the edges onto the berm and eventually becomes a grade with a gradual curve from the ditch to the crest. According to the manufacturers a mile of road such as shown by the diagram can be built by 17 rounds or hauling the machine a distance of 34 miles, or in about 2 days' time.

Data on Elevating Grader Work. I have seen 700 two-horse wagons, holding ¾ cu. yd. each, loaded per 10-hr. day; and, I am informed, that with good management and an easy soil, 700 wagons, holding more than 1 cu. yd. each, can be loaded per 10-hr. day. With three-horse wagons the average 10-hr. day's output on the Chicago Drainage Canal was 500 cu. yd. of top soil.

Mr. N. Adelbert Brown, C. E., of Rochester, informs me that an elevating grader was used by Thomas Holihan, in grading streets at Canandaigua, N. Y. The streets were 60 to 75 ft. wide between property lines, and 36 ft. between curbs. A traction engine was used to haul the grader, and there was no trouble in turning the engine and grader between the walk lines, which was easily within 50 ft. of space. "The efficiency of the machine was not tested fully, due to a lack of teams; but, when teams were available, 50 wagon loads, of 1½ cu. yd. each, were readily loaded in an hour. The machine was satisfactory in stone and gravel

roads and stiff clay, but in light sand in some cases refused to elevate." This latter is true, however, of all elevating graders in any dry sand that will not turn a furrow.

Fred T. Ley & Co., of Springfield, Mass., inform me that elevating graders were used by them on electric railway work in central New York state, both with traction engines and with horses. They averaged 400 to 500 cu. yd. loaded into wagons per grader per day.

No matter how short the lead, a team hauling earth from a grader must perform a large percentage of waste labor following the grader, and this is equivalent to adding about 400 ft. to the "lead."

It is necessary to spread the earth on the dump to prevent stalling of the dump wagons, but by using a leveling scraper the cost of this item can be reduced below the cost of hand leveling.

In *Engineering-Contracting*, Apr., 1906, there is an article by Mr. Daniel J. Hauer, giving costs of elevating grader work on 7 railroad jobs. The limitations of the grader for narrow through cuts are well shown. The average cost was as follows for an average "lead" of 800 ft., with an average daily output of 288 cu. yd. per elevating grader:

	Per cu. yd.
Loading	$0.100
Hauling	0.127
Dumping and spreading	0.029
Water boy	0.002
Foreman	0.010
Total	$0.268

The wages of the grader operators were $1.50 per 10-hr. day; laborers, $1.50; two-horse team and driver, $4.60; three-horse team and driver, $6.25. The $0.268 does not include any allowance for interest, repairs and depreciation. This is probably as high a cost for elevating grader work as will be likely to occur with the same length of haul and the same rates of wages.

Cost of Elevating Grader Work on the Belle Fourche Dam. In *Engineering News*, Apr. 2, 1908, Mr. F. W. Hanna gives the cost of work during 1906–07 on the Belle Fourche Dam, South Dakota. The material, consisting of a heavy adobe clay with occasional layers of shale, was excavated and placed by graders and wagons and by steam shovels, cars and locomotives simultaneously. The cost of the steam shovel work is given in Chapter XIII.

Two Western elevating graders of standard size were drawn by 16 horses or by two 32 hp. 21-ton traction engines. Material was loaded into 24 3-horse dump wagons, each holding 1.1 cu.

yd. of material as measured in place. The water-measure capacity was 1.5 cu. yd. The average length of haul was approximately 1,300 ft. The material after being dumped was spread with a 6-horse road leveler and rolled in 6-in. layers by a 21-ton traction engine and road roller.

The cost of common labor was $2.25 to $2.50 and of horses $1.15 per day of 10 hr. Coal cost $10.50 per ton delivered. The cost as given in the accompanying table includes superintendence and overhead charges, which amounted to about 2.2 ct. per cu. yd.

TABLE COST OF GRADER WORK ON BELLE FOURCHE DAM EMBANKMENT FOR 1906 AND 1907.

(Total yardage for both years, 199,000 cu. yd. Daily 10-hr. average per grader, 566 cu. yd.)

	Cost per cu. yd.
Excavating —	
Labor	$0.047
Depreciation and repairs	0.017
Supplies	0.012
Total excavating	$0.076
Hauling —	
Labor	$0.126
Total hauling	$0.126
Spreading —	
Labor	$0.016
Depreciation and repairs	0.001
Total spreading	$0.017
Rolling —	
Labor	$0.008
Depreciation and repairs	0.005
Supplies	0.008
Total rolling	$0.021
Watering —	
Labor	$0.011
Depreciation and repairs	0.011
Supplies	0.003
Total watering	$0.025
Grand totals —	
Labor	$0.208
Depreciation and repairs	0.034
Supplies	0.023
Total	$0.265

Cost of Stripping a Gravel Pit. George Rathjens in *Engineering and Contracting*, Jan. 19, 1910, gives the following:

During the month of September, 1909, the following record was made in stripping a gravel pit in the Dakotas. The pit in question was evidently of glacial origin and was covered with a sandy loam, there being a number of pockets of varying depths, the maximum about 10 in. The length on the railroad right of way was 3,000 ft., the width 50 ft. and the length at the back 2,000 ft., one end being square with the railroad. The contract called for stripping a width of 250 ft., the material being carried from the track towards the back of the pit and deposited in winrows with a base of 45 ft. A part of the material was used for grading the straight storage tracks paralleling the main line, the pit being on a curve.

The outfit consisted of 1 Austin grader, 6 1¼ cu. yd. dump wagons, 4 No. 2 wheelers and 2 plows. Two more wagons could have been used to advantage, as the grader sometimes had to wait for wagons.

The grader usually worked a strip or line about 350 ft. long by 35 ft. wide, with an average haul of about 150 ft., the longest haul being 220 ft. Wheelers were used where pockets were found. The contractor owned his teams, but teams with drivers were worth $5 per day when hired. Hay and other feed was purchased from nearby farmers. During the month mentioned the contractor stripped 19,970 cu. yd. at the costs here given:

Austin Grader:	
2½ teams on push,* 24 days at $5	$ 300
8 teams on machine, 24 days at $5	960
Dump Wagons:	
5½ teams, 24 days at $5	660
Wheelers:	
3 teams on wheelers, 11 days at $5	165
1 team on plow, 11 days at $5	55
1 team on scraper, 11 days at $5	55
Labor:	
1 foreman, straight time	85
1 mucker, 24 days at $2	48
1 corral man, 28 days at $2	56
2 Austin grader drivers, 24 days at $2.25	108
Total	$2,492

* Teams on push operated the elevator, team power being the only power used.

The cost is almost 12½ ct. per cu. yd.

The total time was 28 days, as shown by corral man's pay, but 2 working days were lost on account of rain and 2 on account of dust. The expense of feeding teams and cost of repairs and interest are not included.

Coal Stripping with an Elevating Grader. *Engineering and Contracting*, June 19, 1918, describes the methods employed in stripping an 80-acre track of coal land in Kansas.

The coal property is a rectangular piece of land, extending throughout its full length along the railroad right of way. The two small preliminary pits taken out with fresnoes comprise the corner nearest the railroad and highway. The remainder of this strip bordering the railroad was to be left to the last, when it would be taken out with an elevating grader.

In his plans the contractor divided the remainder of the tract into five box-pits about 700 ft. long, as shown in the diagram. The first of these box-pits, to be stripped, is 72 ft. wide at the top and 60 ft. at the bottom. The next pit will bottom 40 ft.

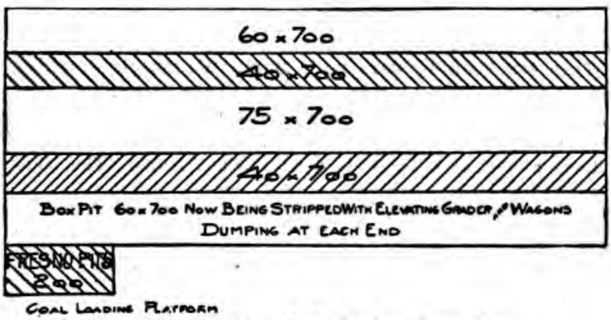

Fig. 5. Diagram of Stripping Operation.

wide; the third, 75 ft.; the fourth, 40 ft., and the last, running to the edge of the property under lease, 60 ft.

These five box-pits will not be stripped in continuous succession but alternately, the two inside pits (shaded in the diagram) each 40 ft. wide at the bottom and 700 ft. long, being left until the last. When he comes to strip the two inside pits, by using a longer elevator on his machine, the contractor expects to be able to cast fully two-thirds of the material, which will be a very inexpensive operation and will reduce his yardage cost materially. The slopes will be taken out eventually with fresnoes.

The average cut in the pit now being stripped is 16½ ft., with a maximum of 21 ft., and the material is a very tough gumbo and hard shale, covering 35 in. of coal. For stripping the contractor is using a Western standard elevating grader, drawn by a Reeves tractor, loading into Western 1½-yd. dump wagons, three horses to a wagon. The cut is being made with one side per-

pendicular and the other, toward the adjoining box-pit, with a slope of ½ to 1. He finds eight wagons the proper number for economical work and under favorable conditions can move from 750 to 800 cu. yd. of material in a 9-hr. day. Three-horse teams are necessary because as the pit grows deeper the load must be lifted to a considerable height. The wagons work both ways out of the pit, there being a dump at each end.

The working force consists of an engineer, steersman for the tractor, machine man, eight drivers, a dump man, a man for the water team and a corral man. The machine man is also a blacksmith. Repairs are made on rainy days when possible. The contractor acts as his own foreman. If the machine man is called away for blacksmith work while the machine is operating, the contractor takes his place. When the contractor is called away the machine man acts as foreman. This organization works 9 hr. a day, from 7 to 12 and from 1:30 to 5:30.

A Trap for Loading Cars with Dump Wagons is described in *Engineering and Contracting*, April 16, 1919, as follows:

An interesting method of trap loading with Western dump wagons was employed in the construction of an 8-mile railroad for the development of silica beds near Fowler, Kans. The illustra-

Fig. 6. Trap for Loading Cars with Dump Wagons.

tion, from the *Earth Mover*, shows the method of loading stripping material which was used for ballast. The elevation of the hill where the stripping took place was slightly above the level of the platform. In the platform was a trap door on hinges, so fastened that it could be tripped at will. The wagons from the elevating grader were driven successively to the platform and

dumped upon the trap door without stopping the teams. After each load had been discharged the door was tripped, letting the material fall into the car below. Such an arrangement permits a free movement of the team and does not restrict the output of the elevating grader.

Elevating Grader on Railroad Work. Mr. J. R. Taft presents some interesting data of the methods and cost of operating an elevating grader on railroad construction in *Engineering News*, Sept. 10, 1914. The use of this machine for taking out railroad cuts is unusual, as local conditions generally do not permit the use of such an outfit, except for work spread over comparatively large areas and of shallow depth. Owing to the rolling character of the country, consequent long hauls, and apparent absence of rock or stone, the contractor decided to take out cuts by elevating grader and wagons. The excavation altogether amounted to about 20,000 cu. yd. place measure, 94% of this amount being removed by machine, the remaining 6% being unfavorable for machine work because it was either root-bound surface soil or high places at the bottom of cuts. The work was done on the Halit and Northern Railroad in Livingston County, N. Y.

The machine used was an Austin elevating grader, hauled by a 20-ton steam tractor. The wagons were 1½-yd. bottom-dump wagons, drawn by 3 mules each. The outfit was supplemented with a light grading equipment of Fresno, wheel and drag scrapers used in places inaccessible to the grading machine.

The material was a stiff clay, hard when dry and plastery and sticky when wet. Wet weather prevented work in such material and the grading machine could not be used during the greater part of November, December and January.

A cut 20 ft. wide was too narrow for the machine to work in, and it was necessary to over-cut the prescribed section to a total width of 30 ft. Even a 30-ft. cut did not provide sufficient room for loading all the material into wagons working in the cut when working along the center line. Therefore when taking out the middle third of the width, considerable re-handling was necessary, the material being cast up on the sides by the machine, and later raked down by slopers, to a position from which it could be again picked up and loaded into wagons. When the machine was working alone, the teams were used on light grading elsewhere. A wagon load of a little less than 1 cu. yd. place measure was removed for each 6 ft. the machine travelled. Stones embedded in the tough material were caught by the plow point and caused severe strains to the whole apparatus, which were relieved by the shearing of the bolts in the plow frames. Many hundreds of bolts were broken and replaced causing many unrecorded delays of from

5 to 15 min. each. The total time of 119 days during which the maching was working in the cut (not including the removal of about 4,000 cu. yd. from the marl pit) was classified as follows:

	Days	%
Unnecessary delays.		
Lack of duplicate parts	6	5
Delays by work elsewhere on the line	5	4
	11	9
Necessary delays.		
General repairs	6	5
Wet ground	43	36
Total	49	41
Total delays	60	50
Machine and operation	59	50
Total working time	119	100

Considering the work as a whole, it was not executed under favorable conditions. Eliminating the item of wet ground from the total working time of 119 days, 76 days were consumed in excavating about 20,000 yd., giving a daily average of about 260 cu. yd. In areas that were not so constricted about twice this outp..t might be expected.

The daily cost of operations was as follows:

(A) At Working Point

Foreman (member of firm)	$ 6.00
Tractor engineman	4.00
Tractor steersman	2.00
Machine operator	3.00
Tank-wagon driver	2.00
Extra tank wagon with driver	5.50
Total	$22.50
Fuel, oils, etc., for tractor	5.00
Six dump-wagon drivers, at $2	12.00
Two dumpmen, at $2.25	4.50
	$21.50
Total at working point	$44.00

(B) At Camp

One blacksmith	$ 3.00
One barnman at $40 per month and board	2.00
One cook at $40 per month and board	2.00
Total	$ 7.00
Corral expenses for 25 head of mule stock	20.00
Total at camp	$27.00
Total of (A) and (B)	$71.00
For insurance, interest, depreciation, etc., 12½%	9.00
Grand total	$80.00

Assuming $80 as a fair figure for daily expenses, the cost of moving 260 cu. yd. per day was about 31 ct. per cu. yd. Board

with lodging in camp was furnished the men at $4.50 per week, which was practically at cost. Corral expense was based on oats at 64 ct. per bushel, loose hay at $21 per ton, and straw at $10 per ton; all haulage by the contractor.

Tractors for Pulling Graders. Prof. A. B. McDaniel in *Engineering Record*, July 31, 1915, gives the comparative cost of using animals and gasoline tractors, for pulling elevating graders. His estimate is based on average working conditions on road construction in comparatively level country, where the earth is to be removed from the side of the road to the center. The detailed estimate and cost is given as follows:

COMPARATIVE COSTS OF EXCAVATION WITH ANIMAL POWER AND GASOLINE TRACTOR

Animal Power	
7 teams, at $2.50	$17.50
2 drivers, at $2.50	5.00
1 operator	3.00
Total labor cost	$25.50
General:	
Interest on investment at 6%	$ 1.20
Depreciation, based on 10-yr, life	2.00
Repairs and general expenses	1.30
Total general expenses	$ 4.50
Total cost for 10-hr. day	$30.00
Excavated per day	800 cu yd.
Cost per cu. yd.	3.75 ct.
Gasoline Tractor	
Labor:	
1 engineer	$ 5.00
1 operator	3.00
Total labor cost	$ 8.00
Power:	
Gasoline, 30 gal., at 15 ct.	$ 4.50
Cylinder oil, 1½ gal., at 36 ct.	0.54
Grease, 2 lb.	0.20
Repairs, waste, etc.	0.76
Total power cost	$ 6.00
General:	
Interest on investment at 6%	$ 2.40
Depreciation, based on 10-yr. life	4.00
Repairs and general expenses	1.60
Total general expenses	$ 8.00
Total cost for 10-hr. day	$22.00
Excavated per day	1,000 cu. yd.
Cost per cu. yd.	2.2 ct.

When it is necessary to carry the earth along the road, as in the making of cuts and fills, dump wagons must be used. For

a haul of 300 ft., one elevating grader can handle five 1½-yd. wagons, and one additional wagon is needed for each 100 ft. in additional length of haul. If the cost of a wagon and driver is $5 per 10-hr. day, and of a foreman, $3 per day, the cost will be increased from about 8 to 12 ct. per cu. yd.

A New Excavating Machine. *Engineering and Contracting*, Jan. 6, 1916, describes the excavator shown in Fig. 7, the essential features of which are gang plows and a scoop. The machine plows seven furrows, 6 to 12 in. deep, and the scoop handles 56 cu. ft. at each trip. The machine is designed for loading earth

Fig. 7. New Type of Elevating Grader. Made by L. C. Wood & Co., Alden, Ia.

into dump wagons in railway grading, reservoir dam construction, and in ditching for irrigation and road work.

It is operated by a 35-hp. double cylinder traction engine, constructed with a winding drum and anchors so that the engine remains stationary while the excavator is in operation. The machine is drawn ahead about 7 ft. for a load then, without stopping the engine, the scraper is unlocked, fills and is drawn up the track and dumped onto the conveyor. The conveyor discharges into dump wagons at either side of the machine.

The machine is 8 ft. wide and 38 ft. long. It weighs about 12 tons. About 150 ft. of 1⅛-in. steel cable is used so there can be several loads handled without moving the engine. The machine

is drawn from place to place behind the traction engine. It is ready to work as soon as the motor on the machine is started, and begins loading as soon as the engine is unhooked, the cables hooked together and the engine run out to the end of the cable. The small motor on the machine furnishes power to operate the conveyor, to control the plows, to steer the machine and to raise and lower the front end of the machine. When the machine is working the front wheels are on top of the ground and the rear ones travel behind the scraper where the plowing has been picked up. The machine, therefore, always works on the level.

In operation one man is required on the machine and two on the engine. The engine is of special design for operating the machine. Both are built almost entirely of steel and steel castings. The machine is constructed to handle very hard material, such that if plowed with teams, three or four teams would be required on a single plow. A full load is handled in 20 sec. and, in service, from 80 to 100 loads are handled per hour.

A Wagon Loading Trailer. The Insley Mfg. Co. make the machine shown in Fig. 8. This machine is hooked to the back of a wagon after the roadway has been torn up by the rooter plow, and the four-horse plow team is used as a snatch team in grading

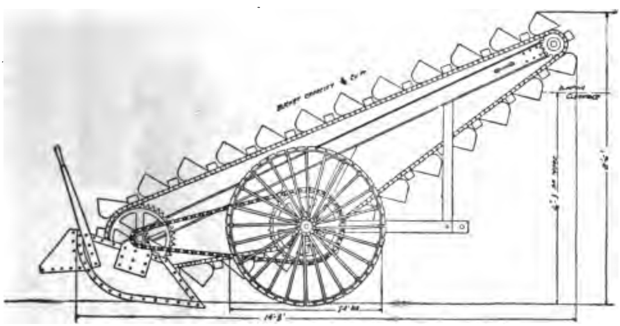

Fig. 8. Wagon Loading Trailer.

and loading. This machine will load 6 wagons of 1½ cu. yd. capacity in 20 min. and should average 24 cu. yd. per hr., taking the place of 12 shovelers and loading a wagon in one-half the time.

Bucket-Elevator Wagon Loader. A machine of this type is made by the George Haiss Mfg. Co. of New York. This is a bucket conveyor mounted on a steel frame wagon body and op-

erated by a 7½-hp. motor or gasoline engine. The machine weighs 3000 lb. and is designed for use on storage piles and in sand and gravel pits. Cost data on its use in handling gravel from a storage pile are given in *Engineering and Contracting*, May 16, 1917. Comparative test of this work by hand labor and by the use of the loading device showed the following results:

Hand labor.	
Loading wagons, 8 laborers, 3 yd., 13.00 min. @ $0.25	$ 435
Loading auto truck, 8 laborers, 2½ yd., 10.00 min. @ $0.25	.415
Cost of auto truck @ $1.00 per hour	.160
Cost per 5½ yd.	$1.010
Cost per yd.	.184
Wagon loader.	
Loading wagons, 2 laborers, 3 yd., 4.8 min. @ $0.5	$ .040
Loading auto truck, 2 laborers, 2½ yd., 4.0 min. @ $0.25	.033
Cost of auto truck @ $1.00 per hr.	.066
Power @ ½ ct. per cu. yd.	.028
Oil, grease, interest on investment	.010
Cost per 5½ yd.	$0.177
Cost per yd.	$ .032
Cost per yd. hand labor	.184
Cost per yd. machine	.032
Amount saved per yd.	$0.152

The above saving is entirely exclusive of supervision and overhead charges.

Fig. 9. Haiss Bucket Elevator for Loading Wagons.

The digging or feeding device used with the Haiss loader is shown in Fig. 10.

Loading Machine for Surface or Underground Work. A loading machine, specially designed for underground work, has been placed on the market by the Wellman-Seaver-Morgan Co., Cleveland, O. This machine digs loose ore, dirt or muck by a continuous scooping process — the material being taken up by scoops or buckets on an endless chain elevated and dropped into a hopper which feeds to a conveyor belt which in turn loads into a car. The scooping mechanism is so pivoted that it can dig to the

Fig. 10. Propeller Feeding Device on Bucket Elevator Loader.

side as well as in front of the machine. The ore, however, being delivered to the conveyor through the hopper, reaches the car behind the loader no matter at what angle the scoop is working. The movement of the scoops is continuous — not reciprocating. The machine is self-propelled and is so dimensioned that it can easily be transferred around the mine. It is claimed that it will load at the rate of over a ton a minute and may be operated by unskilled labor. While designed particularly for underground work, the loader can also be used on the surface for loading coal from piles to cars, removing piles of rock and sand and similar operations. The loader is fitted with motors wound for 230 volts,

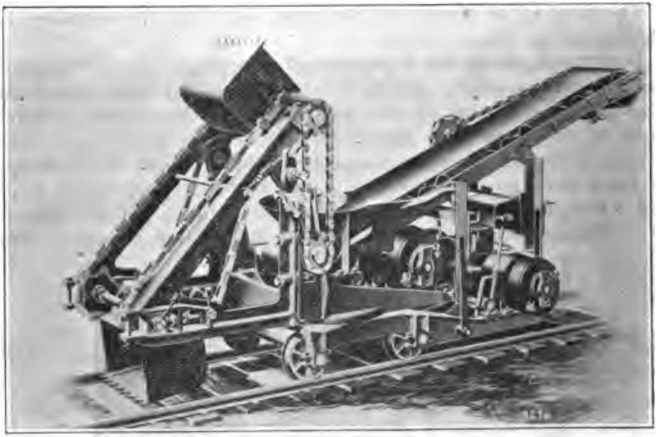

Fig. 11. McDermott Continuous Loading Machine.

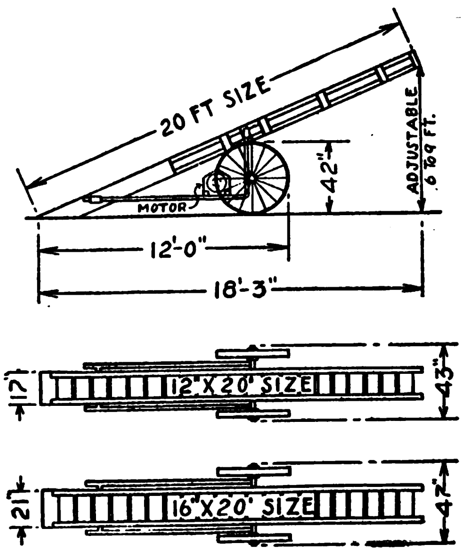

Fig. 12. Scoop Conveyor.

D. C., providing power for all of the operations. The general dimensions of the loader are as follows:

Maximum overall length, 15 ft. 9 in.; maximum height, 5 ft. 6¾ in. with buckets in lowest position; maximum overall height, 6 ft. 7½ in., when machine is in operation; maximum overall width, 4 ft.; gauge of truck wheels, 24 in. Maximum rated capacity with full buckets is 1.75 tons per min. and the average rated capacity is 45 tons per hr. The weight of the complete machine is 8,000 lb.

A Scoop Conveyor for Loading and Piling, made by the Portable Machinery Co. of Passaic, N. J., is illustrated in Fig. 12. The capacity is said to be one ton per minute.

Fig. 13. Undercutting Method of Feeding Conveyor.

An Undercutting Bucket Conveyor Loader, made by the Barber Green Co. of 525 West Park Ave., Aurora, Ill., is shown in Fig. 13.

Bibliography. "Handbook of Construction Plant," Richard T. Dana. "Excavating Machinery," A. B. McDaniel.

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CHAPTER IX

METHODS AND COST WITH SCRAPERS AND GRADERS

Probably some form of log drag has been used for leveling ground since men have known how to plow. A board with handles served the purpose of the log drag and was more easily dumped. From this was evolved the buck scraper to which were fitted wood sides and back to increase its capacity until it became a scoop. This in turn was followed by the steel scoop in various forms. For long hauls the scoop was fitted with wheels.

Cables and hoisting engines were used first to assist the horses in filling scrapers and after that for moving them as well. This permitted the use of larger and heavier buckets. Thus the evolution of the present dragline excavator can be traced, step by step, from the early horse drawn leveling devices.

From the log drag also evolved the leveling scraper or earth hone. The largest size consists of a long blade carried in a frame on four wheels, and is called a road grader or road machine.

An elevating grader, or grader, is an entirely different type of machine. It has a plow that delivers the earth onto an inclined endless belt, as shown in Chapter VIII.

Buck Scrapers. The buck scraper was originally an upright

Fig. 1. Buck Scraper. Width 48 In., Weight 75 Lb.

board about 8 ft. long and 2 ft. high, shod at its lower edge with iron, provided with a tongue for the team in front, and a platform at the rear upon which the driver could stand. During loading the driver would stand on this platform, and if the soil was at all tough, one or two more men would add their weight. Upon reaching the proper place on the embankment the driver would step off the platform and the scraper would flop over or dump automatically. A buck scraper of this size requires four horses to pull it. The material is not carried by any scoop or bowl as with the drag scraper, but is pushed or "drifted" along in front of the blade. The modern road machine, in which the blade is supported by a framework carried by four wagon wheels, is a development of the buck scraper. So also is the smaller leveling scraper.

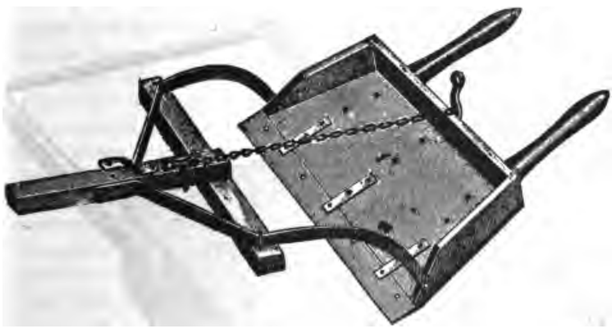

Fig. 2. Tongue Scraper.
(Weight 120 lb.)

Scrapers in Ditch Excavation. From *Engineering and Contracting*, June 23, 1909.

The simplest tool, beside the pick and shovel, with which a trench or ditch can be excavated, is a scraper. In narrow trenches and ditches a drag scraper is used. Shallow trenches can be excavated entirely, excepting the trimming up, with a drag scraper. But for deep trenches, either a long run has to be made to overcome the grade, or a very steep grade has to be ascended with the loads. This naturally makes an economic limit for this work. The writer has used drag scrapers for trenching and has found in the country that deep trenches could be excavated cheaply by first excavating from 4 to 6 ft. with drags, making a slope on the sides of the trench. This slightly in-

creases the yardage, but the scraper work, with a short run, is done at a low cost, and by sloping the top of the banks, much money is saved in the sheathing which is an important item, especially when timber is used.

Fig. 2 shows a drag scraper called a tongue scraper. This scraper is made of wood bound with metal and derives its name from the fact that a tongue is used in it, while with other drag scrapers a tongue is not needed. The tongue scraper is operated in a manner similar to a drag and although it can be used in a trench to advantage, especially at the top, yet it does its best work in shallow ditches, and is an excellent tool for cleaning out trenches.

Fig. 3 shows a Haslup side scraper, manufactured by the Sidney Steel Scraper Co., of Sidney, Ohio. It is meant entirely

Fig. 3. Haslup Side Scraper.

for ditch work, although it can be used in shallow trenches. It gets its name from the fact that its shape allows it to go out the side of a ditch, instead of moving along in the ditch and go out at a runway as a drag scraper has to be worked. The side scraper does rapid work in making shallow, narrow ditches and also in cleaning out ditches. It can also be used in wider ditches. It is made of metal like a drag scraper, and the shape of its handle facilitates its work.

Unless the material is very soft or sandy, in using all of these scrapers it is necessary first to loosen the earth in the trench or ditch by plowing or some other means.

Cost Data on Use of Buck Scrapers. Geo. J. Specht, to whose paper on earthwork reference was previously made, used buck

scrapers in moving very large quantities of earth in building levels and in digging small canals in California in 1882 to 1884. His records of cost are the most complete to be found in print. Horses were hired by the contractors at 37.5 ct. to 50 ct. per day per head, and feed cost 35 to 40 ct. Chinamen were employed as common laborers at $1.15 per day, and white laborers as drivers, etc., received the same plus their board, which cost 40 ct. a day for food alone. Although most of the soil was sandy loam, four to eight horses were hitched to a plow with one driver and one man holding plow.

On the Upper San Joaquin Irrigating Canal, which was cut into a steep side hill, the buck scrapers with four horses attached traveled 400 ft. in making a round trip, and went loaded down a slope of about 1 in 4, returning uphill empty — an unusually favorable condition. Mr. Specht says that 95 round trips were made in 9 hr. by each buck scraper, and as the result of a great many observations he found the average load to be 1.3 cu. yd., although as high as 1.64 cu. yd. in one case. He gives 128 cu. yd. as the average daily output of each buck scraper. It should be observed, however, that the material was all pushed down a very steep hill. From the foregoing it appears that it took 5.7 min. to make a round trip of 400 ft., which is equivalent to a speed of 70 ft. a minute, including stops. This is so extraordinarily slow that we are very much inclined to believe that the actual speed was greater, but that each load was very much smaller than given by Mr. Specht. Mr. Specht gives the following data of cost for Nov., 1882; 27½ days worked:

6-horse plow (with 2 men)	29½ days	at $9.00	$ 265.50
4-horse plow (with 2 men)	15½ days	at 7.00	108.50
4-horse buck scraper (with 1 man)	409 days	at $5.50	2,249.50
2-horse drag scraper (with 1 man)	130½ days	at $3.50	456.75
White man on dump	33 days	at 1.50	49.50
Chinese laborers	328 days	at 1.50	492.00
Chinese bosses	18 days	at 2.00	36.00
			$3,657.75
General expenses (foreman, bookkeeper, blacksmith and hostler)			300.00
55,925 cu. yd. excavated at 7 ct.			$3,957.75

NOTE.— The drag scrapers were used to bring part of the material up from the bed of the canal and deliver it to the buck scrapers; and in doing this, where the round trip traveled by a drag scraper was 225 ft., the output of each drag was 18 cu. yd. in 9 hr., which, it should be observed, was an exceedingly low output. Deducting material moved by drags, we see that still each buck scraper moved 130 cu. yd. in 9 hr.

The foregoing was for November, 1882, but the following

January, 42,241 cu. yd. were moved in 22 days at about the same rate, although there was a cost of about ½ ct. more per cu. yd. for plowing and 1½ ct. more per cu. yd. for additional Chinese labor, presumably for grubbing roots and trimming slopes, although not so stated.

In February some hardpan was encountered, adding still another 1½ ct. per cu. yd. for powder, etc., distributed over the 80,000 cu. yd. moved that month.

In the year of 1884 Mr. Specht built levees. Material was largely sandy loam with some adobe, and the "lead" was about 70 ft.; 90% of the material was drifted up a 1 in 4 slope, using buck scrapers. The first 70,000 cu. yd. was moved at the rate of 55 cu. yd. a day per buck scraper; the slow rate being due largely to inexperience of contractors. Later the same contractors moved 294,000 cu. yd. at the rate of 90.5 cu. yd. per buck scraper a day. The first month, when the levee embankments were being started, the cost was about 10 ct. per cu. yd., but the second month, when the levees had grown higher, the cost was about 12 ct. per cu. yd. The rent and feed of horses we have assumed at $1 a day, and wages of labor and board at $1.50; but Mr. Specht fails to state the number of men and rate of wages, giving sum totals only, and we may be slightly in error in making this last assumption.

Drag Scrapers. A drag scraper, or scoop, or "slip," or "slusher," is a steel scoop, not mounted on wheels, for scooping up and transporting earth short distances, and is drawn by a team. Occasionally a small scraper drawn by one horse is used, but not so economically. The ordinary No. 2 "drag" weighs about 100 lb. and can be pulled full up a 3 to 1 slope. While the listed capacity in some catalogues is as high as 7 cu. ft. for a No. 1 and in other at 5.5 cu. ft., and for a No. 2, 4.5 to 5 cu. ft., actual measurement will quickly show that such listed capacities are excessive, except upon the assumption that the scraper is heaping full; and even then it should be remembered that the earth is loose, and about 20% must be subtracted from the loose volume to get measurement in cut. Trautwine overlooked the shrinkage item and assumed the listed capacities to be correct. Of course, many of the loads, even in ordinary soil, are not full loads; and frequently in stony or rooty soil the load is lost by accidental dumping before the embankment is reached.

Trautwine's table of cost is based on loads of 0.2 cu. yd. place measure(which is about double the actual average), and he estimates a speed of 150 ft. a minute with 15 ft. added to the lead for turning around — although too small an allowance for short leads. The actual speed is about 220 ft. a minute, and the

lost time in loading and dumping (which Trautwine entirely overlooks) is 1/3 to 1/2 a minute. As evidence of the falsity of Trautwine's assumptions we need but call attention to the fact that it is impossible to move 220 cu. yd. in 10 hr. with one scraper as given in his tables on a 40-ft. "lead." The author has never seen an average of one-third that amount maintained, and his records of cost of moving 60,000 cu. yd. of "easy gravel" (lit-

Fig. 4. Drag Scraper Made by American Steel Scraper Co., Sidney, Ohio.

No. 1. Capacity 7 cu. ft.
No. 2. Capacity 5 cu. ft.
No. 3. Capacity 3 cu. ft.

tle plowing required) show that the average output per scraper was 62 cu. yd. in 10 hr. with a lead of 50 ft. and embankment 8 ft. above bottom of pit. Under the same conditions where stiff clay was moved the output was 40 cu. yd. in 10 hr. per scraper, where 20,000 cu. yd. were moved.

Ellwood Morris found the average capacity of the wooden scraper used in his day (1841) to be 0.1 cu. yd. place measure,

and he allowed 1.33 min. lost time in loading and turning each round trip, and assumed a speed of 140 ft. a minute.. The author's experience agrees substantially with his in all but the speed, which the author finds to be 50% greater. It is a very easy matter to err in estimates of speed on short hauls, where teams are continually stopping for one thing or another. While actually walking, unless the drivers loaf, the speed of scrapers is almost as great as wagons.

In this connection it should be noted that most of the data given by Mr. Morris are still usable although nearly 80 years old. His original paper was published in the *Journal* of the Franklin Institute in 1841.

In working drag scrapers on the ordinary short leads there are usually 3 teams traveling in a circle or ellipse of about 150 ft. circumference, so that each team has about 50 ft. to itself, which is none too much. One man loads the scrapers as they go by, and each driver dumps his own scraper. It is evident that with a "lead" of only 25 ft., the actual haul from pit to dump is 75 ft., yet for a lead of 25 ft., Trautwine assumed the low allowance of 15 ft. more, instead of 50 ft. for manœuvering the teams. The actual loads of drag scrapers average for tough clay $\frac{1}{10}$ cu. yd., for gravel $\frac{1}{7}$ cu. yd., and for loam $\frac{1}{5}$ cu. yd.

Railway Work with Scrapers. Bearing out the author's experience may be cited that of J. M. Brown (see *Trans. Iowa Soc. of Engineers*, 1885). In building a railroad embankment (Iowa) 2 ft. high, 20 ft. wide at the base, the distance from the center of the borrow pits at the side to the center of the fill was 33 ft. Large drag scrapers holding 4 cu. ft. of earth when full but 3 cu. ft. of $\frac{1}{6}$ cu. yd. on an average were used. Each team made a trip in 1.5 minutes, and 60 cu. yd. moved per scraper was a good 10-hr. work.

One plow was used requiring at times one team, at times two teams (average 1.5 teams), loosened 360 cu. yd. in 10 hr. One man to every two scrapers was required to load them, and one man to every six scrapers to dump them. There was one foreman to each of these gangs. [N.B.—The author's experience has generally been that one man is needed to load these scrapers, and no man is required to dump them, the driver doing that; but it is generally well to figure in another man to every three teams to be used in grubbing small roots, etc.] Thus with a 33-ft. "lead" Mr. Brown's experience was that, including foreman, it costs 10 ct. per cu. yd., wages being 15 ct. per hour for men and 35 ct. for teams with driver. To this he recommends adding 3 ct. for each added 33 ft. of "lead" which is erroneous, the error arising from his failure to see that the "lost team

time" in loading and dumping is no more for a lead of 100 ft. than for a lead of 33 ft.

Diking with Scrapers. In diking several miles of a creek the writer kept careful record of the cost of excavating 55,500 cu. yd. of sandy gravel measured in cut taken from the bottom of the dry creek bed. This material was excavated by 1,040 team-days (with driver) and 900 man-days of 10 hours each, at a total cost of $5,000, wages being $3.50 a day for teams with driver and $1.50 for men, which is equivalent to 9 ct. per cu. yd. Drag scrapers were used, three in a "string" traveling in a circle about 150 ft. around, although the "lead" was but 50 ft. The bottom of the creek was 50 ft. wide and excavated to a depth of about 2 ft., the material being placed in dikes on each side, the top of the finished dike being 9 ft. above the bottom of the finished channel. About 5 acres of brush were cleared from the banks but not grubbed. There was one scraper holder to each string of three teams, and one plow team to every 6 or 7 scrapers. Each scraper averaged 62 cu. yd. excavated per day, so that each plow averaged about 400 cu. yd. per day, and including plow teams the average output per team was 53 cu. yd. per day.

In diking another creek the material encountered was a rather stiff clay which was plowed with a heavy single team. The finished channel in this case was only 15 ft. wide at bottom, and the top of the finished dikes was 6 ft. above the bottom of the channel. The "lead" was only 20 ft., but the teams traveled as in the preceding case, three in a string, describing a circle or ellipse 150 ft. in circumference. With 540 team-days (including driver) and 620 man-days, wages as before, 20,100 cu. yd. were moved at a cost of 14 ct. per cu. yd., 4.6 ct. being for labor and 9.4 ct. for teams and drivers. To this were added 0.5 ct. for tools, 0.5 ct. for sundry expenses, and 3 ct. per cu. yd. for foremen, making a grand total of 18 ct. per cu. yd. The foreman item would not ordinarily exceed 1 ct. per cu. yd., but in this case frequent rainy spells flooded the creek bed and stopped work, during which time the foreman's pay went on. Not including plow teams, the output per drag scraper team was 37 cu. yd. per day.

The very same gang later, under another and better foreman, moved 15,000 cu. yd. of clay, at the rate of 48 cu. yd. per scraper per day, and including plow teams, of which there was one to every six scrapers, the output was 38 cu. yd. per team-day of 10 hr. There were 8 men, beside drivers, for every 10 teams, so that the cost was 9.25 ct. per cu. yd. for team work, 3.15 ct. for labor, 1 ct. for foreman, and 0.5 ct. for tools and sundries,

making a total of nearly 14 ct. per cu. yd. We believe that it would be difficult to better this output in stiff clay, for the horses and men all worked with energy.

In excavating 2,100 cu. yd. of gravel in a road cut to a depth of about 32 in., the top 8 in. being frozen, 12 men and 8 teams on drag scrapers and plow were engaged 6 days of 10 hr. The haul was 50 to 75 ft. The output was 50 cu. yd. per scraper-day, and 44 cu. yd., per team-day, including plow teams.

Based upon the author's experience we have the following:

Cost Rule for Drag Scrapers. To find the cost per cu. yd. of average earth (1/7 cu. yd. per load) moved with drag scrapers, add together the following items:

1/20-hour's wages of team with driver and plowman for plowing.

1/6-hour's wages of team with driver, lost time loading, dumping and extra travel in turning.

1/20-hour's wages of laborer loading scrapers.

1/6-hour's wages of team with driver for each 100 ft. of "lead," for hauling.

With wages at 30 ct. per hour per man and 15 ct. per horse this rule becomes: To a fixed cost of 16 ct. per cu. yd. add 6.7 ct. for each 100 ft. of "lead." Fairly tough clay, hard to load, will cost one-third more, whereas easy sand or loam will cost one-third less.

Lead in ft.	Cu. yd. per scraper-hr.
25	5.1
50	4.5
75	4.0
100	3.6
125	3.3
150	3.0

The "lead" is the distance from center of cut to center of fill, in a straight line.

Cost of Excavating a Cellar with Drag Scrapers. *Engineering and Contracting*, Jan. 27, 1909, gives the following. The following costs are for cellar excavated in stiff clay. The depth of the excavation was 4½ ft., the building being 30½ x 33 ft., with an angle 5 x 16 ft., cut out of one corner. The number of cubic yards was 155. The costs given include the expense of trunning up the sides. The clay was plowed and then excavated with drag scrapers, the excavated material being dumped on the sides of the bank. At first two teams were used, and an extra man for loading the scrapers. When most of the material was excavated only one scraper was used, and one of the three men was put to work dressing down the sides with a pick. A runway excavated for the scrapers to enter the pit contained 3 cu. yd., making in all 158 cu. yd.

The cost was as follows:

85 hr. team with driver at 50 ct.	$42.50
72 hr. laborer at 15 ct.	10.80
Total	$53.30

The cost per cu. yd. was:

Team work	$0.269
Labor	0.068
Total per cu. yd.	$0.337

This cost could have been reduced by working three scrapers in the gang instead of two, and then one, and by employing an extra man to keep down the sides. With only two scrapers the pace of the teams was slow. This is shown by the fact that only 1.86 cu. yd. of material was moved by a scraper per hour, when at least 3 cu. yd. should have been excavated. Then with only two scrapers, there were times when only one scraper was at work when plowing was being done. With three teams the pace would have been much faster. It would also have been possible to have worked one team overtime and thus have had most of the plowing done when it would not have interfered with the regular work of the scrapers.

The cost per cubic yard should have been from 3 to 5 ct. less than it actually was.

Cost of Grading a Railroad Siding. The following cost in connection with a lead refining plant at Grasselli, Ind., are taken from *Engineering and Contracting,* Mar. 12, 1913. About one mile of railroad grading was necessary for the trackage serving the plant. All the material was sand and was handled by slip scrapers. Very little plowing was necessary. The length of haul averaged about 200 ft. and the maximum haul was about 400 ft. The teams and scrapers with driver were paid 35 ct. per hour. Common laborers received $1.75 per day of 10 hr. The work was done between March 7 and April 28. The average number of teams per day was 9.8.

Excavation, cu. yd.	15,658
Total labor cost	$1,866.00
Cost per cu. yd. ct.	11.9

A "Dirt Bucker" for Making Fills Over Marshy Ground. *Engineering Record,* July 3, 1915, gives the following: For making fills across marshy ground in connection with Idaho State road work, a device called a "dirt bucker," is used. It consists of an ordinary fresno scraper fitted to the forward end of a frame supported on two wheels in the rear, similar to that

of a "hay bucker" such as used on western ranches for moving hay from the field to a stacker. The material is pushed ahead of the team by the frame in making fills across wet, marshy places too soft to hold up the horses. The dirt is first dumped at the end of the fill and the "bucker" is simply used for pushing it ahead, taking the place of dump men. According to Edward S. Smith, Idaho State highway engineer, it has proved very effective and economical.

Grading Across Sloughs with a Push Scraper. The following is from an article by L. V. Martin, appearing in *Engineering and Contracting*, May 7, 1919. During the past 5 years it has been

Fig. 5. Pushing the Grade with a Bulldoser.

the writer's task to grade across a large number of pot holes, sloughs and peat bogs, over which it was impossible to drive teams. These have varied from a few feet in length to a length of 3,000 ft. in one extreme case. During this work the writer has made some deductions as to costs and methods that may be of interest to contractors and engineers.

The most common method of procedure is by what is termed bull-dosing or pushing the grade. This method is particularly adapted to sloughs containing standing water and to short stretches of bog. The grade for this work should be carried from 40 to 60 ft. wide at the base; or in the case of standing

water to a minimum width of 40 to 45 ft. at the water level. Wagons or scrapers are dumped as close to the edge as it is possible to drive the teams and the dirt is then pushed ahead by the bulldoser, as shown in the illustration. A good operator on the bulldoser can handle the dirt from 5 to 6 teams on an average haul of 500 ft., and more as the length of haul increases. With a good operator little time is lost over a straight haul on good ground. The outfit shown was pushing for five No. 2 wheelers on a 400-ft. haul. A heavy steady team is required to handle this pusher. The actual cost per yard over straight haul dirt with a good operator should not exceed 2 ct. per yard, and may even run below this. Unless dirt can be sent both ways from the cut, however, or the fill is long enough to use the full outfit, an elevating grader is not worked at full capacity and the extra cost per yard on this account will be raised to perhaps 6 ct. additional as a maximum.

The outfit shown in the picture was a home-made affair consisting of the front wheels of a dump wagon, a straight telephone pole 8 in. at the butt and 20 ft. long, and a push board braced as shown, shod with a 3-in. by ⅛-in. iron edge on the bottom. It was so made that the pole with board attached could be removed in a few minutes from the wheels and loaded on a wagon. These outfits can, however, be bought from any road machinery firm. This method is much superior to and cheaper than the old one of having shovelers at the end of the grade pushing the dirt off with a shovel.

The Fresno Scraper. The scraper shown in Fig. 6 embodies several features in its construction that have made it a favorite tool for scraper work on the Pacific Coast. The chief peculiarity of the device, aside from its general shape, compared with the ordinary drag scraper, is the arrangement of shoes or runners on which it travels when empty. This scraper was probably first made at Fresno, Calif., whence its name.

In loading and when traveling loaded the scraper travels on the bottom of the bowl, which is made very heavy, being a plate of ¼-in. plow steel, having no runners in the shape of projecting plates or strips. In dumping, the scraper is raised by the rear handle until it rests on the traveling shoes so that the load spills back under the edge of the bowl which is raised off the ground as shown. By varying the height to which the handle is raised the opening under the edge may be made almost any height from an inch up to the full opening shown; this possibility is of particular value in leveling work, since the load can be distributed in a layer of almost any desired thickness. A rope is customarily fastened to the handle. This

is used to prevent the scraper from dumping prematurely, and is allowed to drag when not in use.

The bowl fills more rapidly if drawn across the furrows than if hauled longitudinally with them. The sizes and capacities are given in the accompanying table. The actual capacities

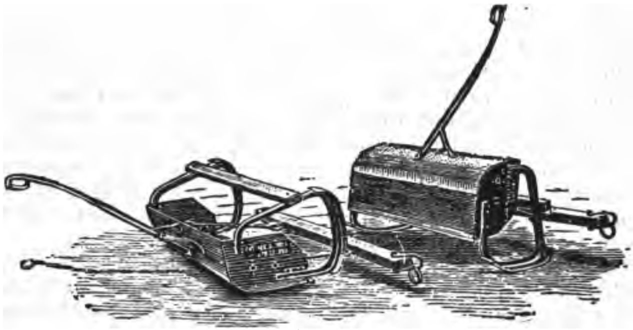

Fig. 6. The Fresno Scraper.

given are for work in average earth on uphill or level hauls. The loads are often from 50 to 100% greater on downhill hauls. No. 1 scraper is generally used, and requires four horses or mules.

FRESNO SCRAPERS

Size	Horses required	Length of cutting edge	Capacity Listed cu. ft.	Capacity Actual cu. ft.	Weight lb.
No. 1	4	5	18	9.54	300
No. 2	3	4	14	7.43	275
No. 3	2–3	3.5	12	6.36	250

Rules for Cost with Fresno Scrapers. The ordinary four-horse fresno scraper has a bowl 13 in. high, 18 in. wide and 5 ft. long, giving a struck measure capacity of slightly more than 8 cu. ft.; but in almost any soil, except dry, running sand, the earth will heap up 6 or 8 in. above the top of the bowl, and will extend quite a distance beyond the front of the bowl. One carefully measured fresno load of clayey earth contained 19 cu. ft. of loose earth, which compacted to 16½ cu. ft. when rammed in 4-in. layers in a box. Several other large loads gave almost the same results after being hauled 100 ft. over a level road.

Mr. Geo. J. Specht has stated that on a downhill haul, loads will average 35 cu. ft. and occasionally run as high as 44 cu. ft. However, this could only occur with light, damp soil and on a

downhill pull where much material could be drifted ahead of the fresno scraper. We have never measured any loads of that size.

On level hauls, or on uphill pulls, it is not ordinarily safe to count on more than ½ cu. yd. (measured in cut) per load, although under favorable conditions the average load may be 25 to 50% greater, while under unfavorable conditions it may be 25% less.

If the delays in loading and dumping are excluded, the team can be counted upon to travel about 200 ft. per minute. It requires some room in which to manœuver scrapers of any kind, no matter what method of handling the teams is adopted. Hence one must not measure the average distance in a straight line from the center of the cut to the center of the fill, and call that the average haul, for that is the average "lead," which is considerably shorter than the actual haul.

In average earth the daily output is as follows when the load averages ½ cu. yd.

"Lead" in ft.	Cu. yd. per fresno, 10 hr.
50	120
100	100
150	87
200	75
250	67
300	60
350	55
400	50

We have never measured any fresno loads that had been hauled as far as 400 ft., and we doubt very much whether fresno loads hauled that distance would average as much as ½ cu. yd., due to the loss that occurs en route.

Cost Rule. To find the cost per cubic yard of average earth (½ cu. yd. per load) moved with fresno scrapers, add together the following items:

1/20-hour's wages of 2-horse team with driver and plowman for plowing.

1/15-hour's wages of 4-horse team and driver, lost time loading and dumping fresno, and extra travel in turning.

1/30-hour's wages of 4-horse team and driver for each 100 ft. of "lead" for hauling. The "lead" is the distance in a straight line from the center of cut to center of fill.

With wages at 30 ct. per hr. per man, and 15 ct. per hr. per horse, this rule becomes:

To a fixed cost of 10.5 ct. per cu. yd. add 3 ct. per 100 ft. of "lead."

For tough clay add one-third to this cost and for easy sand or loam deduct one-third.

Each driver is assumed to load and dump his own fresno.

Cost with Fresnos in Arizona and Cost of Trimming Slopes. *Engineering and Contracting*, Oct. 2, 1907, gives the following: The following is an example of fresno scraper work, done in Arizona in 1894, under one of the editors of this journal. The scrapers were used in grading a railroad bed, the cuts being 10 ft. wide and the embankments 8 ft. wide. The road was narrow gage. Thirteen miles of roadbed were graded, the yardage moved being 70,000, or 5,400 cu. yd. per mile.

The contractor managed his own work, having only foremen in charge of the various gangs directly under him. One man kept the time books, attended to the commissary and also acted as bookkeeper. In this way the general expense account was a small one. The wages paid were as follows:

Time keeper, $50 per month and board.
Foreman, $3 per 10-hr. day.
Foreman, $2.50 per 10-hr. day.
Drivers, $1.70 per 10-hr. day.
Laborers, $1.75 per 10-hr. day.

The men were charged 75 ct. per day for board. The horse feed was hauled by the contractor's teams from his own ranch, and he estimated that the entire cost of feeding and caring for a horse per day averaged 75 ct. This makes a charge for teams as follows:

4-horse fresno scraper, team and driver	$4.75
2-horse drag scraper, team and driver	3.25
4-horse plow, team and two men	7.00
6-horse plow, team and two men	8.50

The charge for the plow includes an allowance of 50 ct. per day for the use of plow and repairs.

It was very difficult for a six-horse plow to break the first foot of earth, but, after reaching that depth, a four-horse plow did the plowing easily. The work consisted of shallow cuts, not over 5 ft. deep; but one cut, about 1,000 ft. long, was 15 ft. deep. More than half the roadbed was embankment, ranging from 5 ft. to 30 ft. fill, the average being from 8 to 10 ft. high. The contractor hauled the material from the cuts into the embankments when the lead did not exceed 200 ft.; beyond that distance he wasted the material from the cuts and borrowed for the embankment at his own expense. He considered this cheaper than to haul it. No record was kept of this extra yardage, as he was paid for the cross section quantities, as though

he had made the hauls. Fig. 7 shows the manner of making an embankment 10 ft. high.

The ditches are plowed on each side of the embankment leaving a berm between the ditch and the toe of the slope. The scraper is loaded in one ditch and pulls onto the embankment keeping straight ahead, crossing the ditch on the other side and turning. Then starting back and taking another load the operation is repeated. For an embankment 10 ft. high, this gives a "lead" of about 40 ft., and a distance to be traveled for each load of 100 ft.

The amount of earth pushed ahead in such a short distance is very large, but the haul is always uphill for the load. Each team has its own men, the scrapers not being operated in gangs as with wheelers and drags, but in separate runs side by side, and, by so doing, a certain pace can be set and maintained, as the foreman can see at a glance when all the scrapers are not being loaded at one time.

Fig. 7. Shape of Embankment Built with Fresno Scrapers.

The driver loads and dumps his own scraper, which effects a decided saving in loading and dumping, as compared with wheel scrapers. A rope on the end of the handle makes this operation easy, the scraper, being balanced on the two arch springs in front, dumps as soon as the lever is lifted. It rides in this position to the pit, and then a jerk on the rope throws the pan back on its bottom ready for loading.

The driver handles his four horses thus: The two outside horses have a "jockey stick" tied to their bits, and each horse's bridle is fastened to the adjoining horse's bridle by a short strap or raw-hide string. The two reins are each divided into two lines, one line going to each horse's bridle, the lines from one rein going to one outside horse, and to the second outside horse from it. Thus the left hand rein pulls the left hand outside horse and the right hand inside horse, those two guiding the other two by the bit straps. The right hand rein controls the other two horses.

No attempt was made to shape the embankment to the dotted lines as shown in Fig. 7, but the scrapers heaped up the dirt

as shown by the heavy lines, and left it so, until the dressing up gang finished off the roadbed.

On the highest embankments the Fresno scrapers could not be worked in topping off the embankments to good advantage, owing to the climb necessary to be made from the bottom of the ditch to the top of the bank, so drag scrapers were used for this work. Since no separate record was kept of this drag scraper work, it will have to be included with the work done by the fresno scrapers.

The cost of the work was:

	Per cu. yd.
General expense	$.003
Plowing	.020
Scrapers	.050
Dressing roadbed	.005
Total cost	$.078

At 5 ct. per cu. yd. for the fresno work, this means 95 cu. yd. moved per scraper per day. If allowance is made for foreman, which is included in the cost of 5 ct., this yardage would be increased to about 105. This amount would be further increased if the drag scraper work could have been separated, and if the additional yardage wasted from the cuts had been measured.

It must be remembered that some time is lost by the fact that plowing cannot go on as the scrapers are working, when the latter are handled in the manner described. Hence, when a "plowing" is cleaned up, the scrapers must be moved to another section that has been freshly plowed.

A point of interest was the method of dressing up this work. Only one man with a pick and shovel was used on the job. He did the work necessary on the slopes, although by careful plowing these were brought down in good shape as the cuts were excavated. He also shaped up the roadbed in the cuts when the scrapers left small places that it did not pay to hold teams to do. All the rest of the dressing work was done by a foreman and three drag scrapers. They took out any excess material left in the cuts and smoothed over the bottom whenever possible. They leveled the embankments down to the proper grade, and, if more material was needed on the bank, they brought it up from the side ditches, see Fig. 7.

A man with some little instruction can become very expert in dressing a roadbed with a scraper in this manner. He holds the drag scraper at various angles, cutting off high places and filling up low places as desired. This trimming work cost ½ ct. per cu. yd. of material moved and not quite a ½ ct. per sq. yd. of roadbed. About ⅛ of this cost was for the man using a pick

and shovel and not quite 1/6 was for the foreman who manipulated the scraper.

This cost of trimming is quite low. It will compare very favorably with trimming done by a road machine and other leveling apparatus. As compared with trimming done by hand on railroads, it is from 1/3 to 1/2 cheaper.

Cost Data on Railway Work in Mexico. The actual cost of work to the contractor on the Cananea Rio Yaqui and Pacific Ry. in 1907 was studied by the company's engineers under Howard Egleston. From the results of their findings, reported by him to *Engineering and Contracting*, Oct. 18, 1911, the following is abstracted:

Camp No. 2, which made the best showing, had ideal fresno work. With the exception of a shallow cut of 280 meters, it was all embankment work, varying from nothing to a maximum of about 8 ft., all material being taken from borrow pits alongside. The work of Camp No. 3 was similar, except that part of it consisted in a fill through swampy ground which had to be built with wheelers. Camp No. 1 worked in a high embankment taking material from borrow pits at the bottom of the embankment.

The mules used were all Northern animals. Among the idle teams shown in the table are included for each camp from two to four horses used by the camp foreman and corral boss. While by no means idle these animals could not well be charged to any of the productive outfits. Mexican drivers were used, and with training they handled the teams well, but it was difficult to keep them steadily at work.

All grading on this Mexican work was done by force account, the contractors receiving a percentage of the cost to pay them for superintendency. The contractors executed the work as they thought best; they furnished such machinery as they thought desirable, and the company paid them rent for the same. They furnished all animals needed at a fixed rate of hire per day. The commissary was managed by them on a percentage.

The accompanying tables are figured in Mexican money. In comparing prices given with similar items in the states these items should be cut in two, as the Mexican dollar equals only 50 ct.

Wages All Outfits. Camp Foreman $200, Grade Foreman $150, Corral Boss $120, Blacksmith $200, Harness Makers $150, Cook $90, Cook's Helper $50, Teamsters $100, Watchman $80 per month. Camp laborers $1.75, Grading laborers $1.75, Fresno and wheeler driver $2.50, Plow drivers $4, Plow holders $4 day, Carpenters $8 per day.

GRADING BY OUTFIT NO. 1 FOR 13 DAYS

Earth Handled 5,595 cu. m. 110 Head of Stock

Distribution	Ct. per cu. m.
Foremanship	$0.04
General camp expenses	.08
Plowing	.09
Moving dirt	.39
Freighting	.04
Rentals wagons and buckboard	.07
Idle animals	.07
	$0.78
Total cost per cu. yd., U. S. money	$0.30

No loose or solid rock on this work.
No explosives used.
Work consisted of both cut and embankment.
Average amount dirt moved per day per fresno, 25.34 cu. m.

31 plows used one day at 60 ct.	$ 18.60
220.75 fresnos used one day at 50 ct.	110.38
1 slip used one day at 50 ct.	.50
0 wheelers used one day at 80 ct.	.00
18 wagons used one day at $1.00	18.00

Total cost hay and barley, $870.00 ÷ 715 team-days gives cost of feed per team-day, $1.22, or per animal-day, 61 ct. Mexican money.

Team days working	593
Team days idle	122
Team days total	715
Team hire per day	$1.80
Team feed per day	1.22
Team cost per day	$3.02

GRADING BY OUTFIT NO. 2

Earth handled 10,136 cu. m. 117 head stock.

Distribution	Ct. per cu. m.
Foremanship	$0.03
General camp expense	.05
Plowing	.08
Moving dirt	.23
Freighting	.02
Rentals wagons and buckboard	.01
Idle animals	.06
	$0.48
Total cost per cu. yd., U. S. money	$0.18

No loose or solid rock on this work.
No explosives used.
All embankment except 280 cu. m. shallow cut.
The higher wages paid prior to 10th inst. would increase cost only $24.12, not enough to alter rate per cu. m. It is, therefore, not shown.

Idle team-days	216.5
37.5 plows used one day at 60 ct.	$ 22.50
236.5 fresnos used one day at 50 ct.	118.25
1 buckboard, 10 wagons, ½ mo. at $30.00	165.00
Total team-days	877.5
Work team-days	661.0

Total cost of hay and barley, $1,045.76 ÷ 877.5 team-days gives cost of feed per team-day, $1.19, or per animal-day, 59½ ct. Mexican money.

Of teams working 22% were on plows.
Of teams working 71% were on fresnos.
Of teams working 7% were on wagons freighting.

Team hire per day	$1.80
Feed per day	1.19
Total	$2.99

Average days work per fresno-team, 42.86 cu. m.

GRADING BY OUTFIT NO. 3

Earth Handled 5,837 cu. m. 77 Head of Stock

Distribution	Ct. per cu. m.
Foremanship	$0.036
General camp expense	.048
Plowing	.088
Moving dirt	.250
Freighting	.016
Rentals wagons and wheelers	.041
Idle animals	.054
	$0.533
Total cost per cu. yd., U. S. money	$0.20

Cost of handling dirt per cu. m., .533 ct. Mexican money.
No loose or solid rock on this work.
Alternating cut and embankment.
Average amount dirt moved per day fresno and wheeler, 41.54 cu. m.

30 plows used one day at 60 ct.	$ 18.00
117.5 fresnos used one day at 50 ct.	58.75
2.5 slips used one day at 50 ct.	1.25
23 wheelers used one day at 80 ct.	18.40
6 wagons used one day freighting at $1.00	6.00

Total cost hay and barley, $646.64 ÷ 481¼ team-days gives cost of feed per team-day, $1.34, or per animal-day, 67 ct. Mexican money.

Team days working	380.75
Team days idle	100.50
Team days total	481.25
Team hire per day	$1.80
1 team feed per day	1.34
Team total cost per day	$3.14

A cu. m. is equal to 1.31 cu. yd., so the cost of this work expressed in cu. yd. is 76.5% of the cost here given.

A Low Cost of Fresno Work. Walter N. Frickstad in *Engineering and Contracting*, Nov. 3, 1909, gives the following: The usual practice is to operate fresno scrapers in runs of three to eight, according to length of haul. A laborer to load usually works with each run. But in light ditch work frequently each team works independently and the driver loads his own scraper. Except in finishing a bank, or in other special cases, the driver dumps his own load.

The fresno is generally limited to a haul of 200 or 300 ft., though of course the nature of the contractor's available equipment frequently modifies that. It requires less time and labor

to load and unload than does a wheeler, but the expense of the two extra horses balances those items when the haul exceeds 200 or 300 ft. It is especially useful on highways, on light railroad work, on irrigation and drainage ditches where the cut makes the bank or is wasted, and for loading large cuts.

As with all methods of excavating earth, the output varies widely according to the conditions. The writer has records ranging from 28 to 130 cu. yd. per scraper per day. The cases given below are fairly typical, however. The first four cases relate to work done by contract on the Truckee Supply Canal, for the Reclamation Service, near Wadsworth, Nev., in 1904. In these cases, the wages of drivers and laborers were $2 per 8-hr. day, rent of horses $10 per month, being about 40 ct. per working day, plus 40 ct. for feed. A fresno and harness is counted at 10 ct. per day, plow and harness at 20 ct. All camp and general expenses are excluded, and no deduction is made for profit on men's board. Board was 75 ct. per day, including days of idleness. All working day are of 8 hrs., but the horses were driven accordingly.

Following is a record made under most favorable conditions, in January, 1904. Weather, clear and cold; soil dry, breaking readily, being loam, sand and clay in irregular beds; earth moved from ditch to make the base of both banks of canal, extreme lift being about 10 ft.; a small amount of earth hauled as much as 200 ft.:

Foreman, 15 days at $4.50	$ 67.50
4-horse fresno and driver, 84 days at $5.30	445.20
6-horse plow, driver and holder, 13 days at $9	117.00
Labor, clearing, helping plow holder, etc., 30 days at $2..	60.00
Labor, loading scrapers, 32 days at $2	64.00
Total, 10,219 cu. yd.	$753.70

Deducting $38 as the cost of clearing, the cost per yd. was 7 ct. per cu. yd. It shows 122 cu. yd. moved per scraper per day, and it is certain that the average would have been 130 cu. yd. had all hauls over 100 ft. been eliminated. Owing to careless dumping, however, and the resulting large amount of sloping, the final cost was much larger than shown here.

The second case is typical of a large cut, being the approach to a tunnel. It covers December, 1903, January, February, March, April and part of May, 1904; weather generally clear and cold, except few warm days in April and May; soil dry solid silt and cube clay, which would not pile high in scraper; average force employed, 8 fresno first two months, afterwards 12; excavation on side hill, extreme cut over 60 ft., with 15 ft. to 30 ft. on low side; material wasted into gulch below, much of it 60 ft.

below grade of canal; most of material hauled downward about 30 ft. horizontally 100 to 200 ft. Actual wages varied from these figures, especially plow driver and holder, but are held uniform for comparison.

Foreman, 4¾ months at $80	$ 380.00
4-horse fresno and driver, 1,192 days at $5.30	6,317.60
4-horse plow, driver and holder, 74 days at $7.40	547.60
6-horse plow, driver and holder, 47 days at $9	423.00
Labor, loading, estimated 240 days at $2	480.00
Labor, sloping and miscellaneous, estimated 184 days at $2	368.00
Labor, helping plow holder, estimated 50 days at $2	100.00
Total, 71,567 cu. yd.	$8,616.20

This is almost exactly 60 cu. yd. per fresno per day at a cost of 12 ct. per cu. yd. This cut was not considered to have been well managed. Six or more foremen were in charge successively, and the work dragged noticeably. Other similar cuts, better managed, averaged 65 to 70 cu. yd. per scraper per day.

Following is a record of extremely difficult conditions. The earth was thoroughly mixed with stone, in all sizes up to 5 cu. ft. The greater part of these had to be taken to the outer edge of the embankment. The material was hard to plow and harder to load. It was all used in making the banks, mainly on one side, with little longitudinal haul.

Foreman, 16.5 days at $3	$ 49.50
4-horse fresnos, 61.5 days at $5.30	325.95
2-horse stoneboat, 11.2 days at $3.65	40.88
4-horse plow, etc., 6.5 days at $7.40	48.10
6-horse plow, 5.2 days at $9	46.80
Labor, loading scrapers and stoneboat, 76.2 days at $2	152.40
Total, 3,800 cu. yd.	$663.63

Supposing the 11.2 stoneboats to have been equal to 3½ fresnos, this would give 58.5 cu. yd. per day per fresno. The cost would be about 17½ ct. per yd. This work was well directed, and showed a surprisingly high yardage for the force employed, but the long haul accounts for it.

Following is a record that illustrates the effect of haul. Weather was dry and cold, soil dry sand and silt; haul averaging 600 ft.; foreman the same as the above.

Foreman, 18 days at $3	$ 54.00
4-horse fresno and driver, 170 days at $5.30	901.00
4-horse plow, driver and holder, 9 days at $7.40	66.60
Labor, 49 (probably 22 loading and 27 finishing) at $2.	98.00
Total, 28.8 cu. yd. per fresno per day	$1,119.60

Following is a more itemized record of work during April, May and June, 1906, near Fallon, Nev., by Government forces, on an irrigation canal. Weather hot and dry; soil, mainly compact sand, with some gravel, loam and hard clay; ditch about

20 ft. wide on the bottom, slopes, 2 to 1, bank 7.5 ft. above grades, 6 to 12 ft. wide on top, location generally along a flat sidehill; banks generally made from cut, but one hill had a cut of 20 ft. and the material was wasted beyond a 50-ft. berm or hauled 200 or 300 ft. to reinforce the banks across the adjoining depressions. Another short hill was hauled an average of 150 ft. either way. The right of way was cleared of light brush, and berm plowed before building banks, the slopes were carefully trimmed, and the bottom finished to grade stakes. The working day was 8 hr. The small amount of finishing labor shows how well that work can be done by scrapers.

Foreman	$ 101.00
Sub-foreman	6.00
4-horse fresno drivers, $2.25	692.42
Scraper holders, $2.25	241.31
6-horse plow driver, $2.75	62.55
Plow holder, $2.75	68.05
Laborers, cleaning, finishing, $2.25	16.87
Horses (hired), $0.333 day	464.83
	$1,650.03
Cu. yd. excavated	27,629
Cu. yd. per scraper day	89.75

Following is the July record of the same outfit, on a piece of ditch with less haul and less deep cutting. Labor was scarce, very unsatisfactory, many teams were idle each day, and the foreman was away on a spree for the first twelve days. Appended also is a complete record of the camp expenses, all of which are chargeable to this work. The latter indicate how total expense may differ from field or excavating expense.

Excavating Expense:

18 days foreman at $12.50 per mo.	$ 67.50
34 days sub-foreman at $95 per mo.	107.67
354¾ days 4-horse fresno driver at $2.25	798.19
2 days 2-horse fresno driver at $2.25	4.50
4 days 4-horse tongue scraper driver at $2.25	9.00
1¾ days 2-horse tongue scraper driver at $2.25	3.93
119½ days scraper holder at $2.25	268.88
43½ days 6-horse plow driver at $2.75	119.62
43½ days 6-horse plow holder at $2.75	119.62
1¾ days 2-horse tongue scraper holder at $2.25	3.93
1,691 days horses at 33⅓ ct.	563.67
	$2,066.51

Excavation (about), 30,000 cu. yd.
Excavation per scraper, 84.3 cu. yd. per day.
(2-horse fresno counted as one-half of 4-horse fresno. Tongue scrapers not included, as their work was confined to finishing.)

Managing Force:

13 days superintendent at $145 per mo.	$ 60.81
1 month timekeeper	100.00
93 days horses at 33⅓ ct.	31.00
	$191.81

Camp Force:

26½ days blacksmith at $3	$ 92.75
15½ days cook at $60	31.00
15 days cook at $75	37.50
4½ days second cook at $40	5.99
38½ days flunkies at $35	44.91
13½ days labor at $2.25	30.37
42 days 6-horse freight teamster at $2.75	115.50
2½ days 4-horse freight teamster at $2.25	5.62
17 days 4-horse freight teamster at $2.50	42.50
1½ days 2-horse freight teamster at $2.25	3.37
396 days horses at 33⅓ ct.	132.00
1,594 days idle horses * at 33⅓ ct.	531.33
Subsistence	472.00
Supplies	71.16
Forage	1,634.33
	$3,250.33

* Idle horses includes working stock on Sundays and holidays, being six days.

Deduct board of men at 75 ct. per day, except Superintendent and kitchen force, about $730.

Another contractor, in the spring of 1905, excavated 125 to 130 cu. yd. per day per fresno. The exact record of labor is not at hand, but it can be approximated. The soil was sand and light loam. The cut generally made the banks. The ditch was narrow, and ranged from 6 to 7½ ft. deep, from bottom grade to top of bank. Scrapers worked singly, going down one bank and up the other alternately. Each driver loaded and dumped his own scraper, except one finishing scraper. A two-horse plow, without holder, loosened the earth for 10 to 12 scrapers. The contractor paid $2.25 per day, and worked 8 hr., while others near by paid $2.00 and worked 10 hr. He therefore had the best men available, and forced both men and horses to their limit. He was fully of the opinion that he would have done no better by working 10 hr. per day. The excavation cost, including practically all the finishing, for 125 cu. yd. per fresno per day might be computed as follows for a maximum:

4 horses, fresno and driver	$5.30
1-10 of 2-horse plow and driver at $3.95	0.395
1-10 of loader	0 225
1-10 of foreman at $4	0.40
Total per scraper day	$6.32

This is 5.06 ct. per cu. yd.

The Oakland Revolving-Bucket Scraper. *Engineering News*, Oct. 21, 1915, gives the following: A novel scraper developed from the fresno type is being marketed by the Graves-Spears Road Machinery Co., of Oakland, Calif. Four sizes are made—with 5-, 6-, 7- and 8-ft. buckets.

A long steel bucket or bowl is pivoted in a stiff steel frame which is carried on shoes forward and wheels at the rear. The driver rides, loading and dumping with a foot lever. He does not have to pull the bucket back into place, as it revolves and locks when it comes into loading position. For grading it can be held at any angle desired. This scraper sells at from $75 to $200. It is claimed that one 6-ft. Oakland scraper will move more earth than two 5-ft. fresno scrapers.

Fig. 8. Revolving Bucket Scraper.

Wheel Scrapers. The following has been taken from catalogs, excepting the last two columns, which the author has added:

Size of wheeler No.	Depth in in.	Bowl Width in in.	Length in in.	Weight of wheeler in lb.	Catalogue capacity cu. ft.	Actual struck measure cu. ft. of loose earth	1 Actual place measure
1	12	36	36–36	340–450	9–10	7.5–9	6–7.2
2	1[illegible]–13.5	38	33–37	475–500	12–13	8.75	7–
2½	13.5	38	41	575	14	12.15	9.7
3	16	42–44	40–41	625–800	16–17	15.5	12.4

1 Actual place measure, capacity 20% less than loose measure.

Large wheel scrapers, even in light soils, and small "wheelers" in tough soils seldom leave the pit full of earth, but at the back end of the bowl there is usually a wedge-shaped space unfilled where the earth slopes up from the bottom of the pan on a 1.5 to 1 slope. Unless front end gates are used on large scrapers, a similar unfilled space exists at the front end of the bowl, before the team has traveled far, thus reducing the capacities given in last column by 2 to 3 cu. ft. The author has found the average

load (place measure) carried by wheelers is as follows: No. 1, 0.2 cu. yd.; No. 2, 0.25 cu. yd.; No. 2½, 0.33 cu. yd.; No. 3, 0.4 cu. yd.

These loads, however, can be materially increased by the simple expedient of having men with shovels to fill the bowl heaping full when the soil is such that the team cannot fill the bowl. The longer the haul, of course, the better it will pay to so fill the bowl.

A snatch or snap team is generally used with a No. 2 wheeler

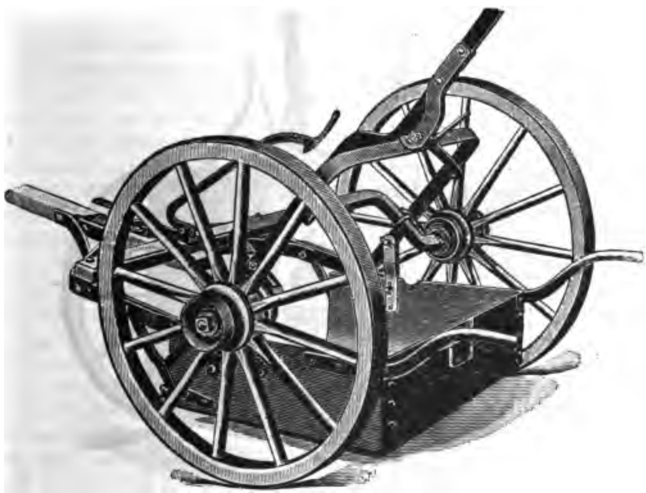

Fig. 9. Wheel Scraper Made by American Steel Scraper Co., Sidney, Ohio.

and always with a No. 3, to assist in loading, but even with a snatch team it is impossible to fill the bowl in tough clay. In such cases by all means use shovelers.

With wheelers, as with drag scrapers, add 50 ft. to the actual "lead" for turning and manœuvering the teams, equivalent to ½ minute of team time each round trip. Another ½ minute is lost in loading and dumping, and still another ½ minute helping load the scrapers.

The lightest No. 1 wheelers made are to be recommended where leads are very short and rises steep, that is wherever drag scrap-

ers are ordinarily used, for they move earth more economically than drags. Where soil is very stony, or full of roots, drag scrapers are to be preferred, since they are more easily and quickly loaded under such conditions.

The method of handling No. 1 wheelers is the same as that above given for drags. When actually walking a wheeler team averages 200 ft. per minute.

Rules for Costs with Wheeler. The following rules of cost with wheelers are based upon careful timing of individual teams

Fig. 10. Wheel Scraper After Load is Dumped.

checked by large excavations. The rules, moreover, will be found to agree closely with published data where conditions have been similar.

Rule I. To find the cost per cu. yd. of average earth moved with No. 1 wheel scrapers (1/5 cu. yd. load), add together the following items:

1/20-hour's wages of team with driver and plowman for plowing.

1/6-hour's wages of wheeler team with driver, "lost time" loading and dumping and extra travel in turning.

1/15-hour's wages of man loading scraper.

$\frac{1}{12}$-hour's wages of wheeler team with driver for each 100 ft. of "lead" for hauling. With wages at 30 ct. per hour for men and 15 ct. per hr. per horse, the rule becomes: To a fixed cost of 16.5 ct. per cu. yd. add 5 ct. per cu. yd. for each 100 ft. of "lead."

Rule II. To find the cost per cu. yd. of average earth moved with No. 2 wheel scrapers ($\frac{1}{4}$ cu. yd. load), using no snatch team, add together these items:

$\frac{1}{20}$-hour's wages of team with driver and plowman for plowing.

$\frac{1}{6}$-hour's wages of wheeler team with driver for "lost time" loading and dumping and extra travel in turning.

$\frac{1}{15}$-hour's wages of man loading scrapers.

$\frac{1}{15}$-hour's wages of man dumping scrapers.

$\frac{1}{15}$-hour's wages of wheeler team with driver for each 100 ft. of "lead" for hauling. With wages at 30 ct. per hr. for men, and 15 ct. per hr. per horse, this rule becomes: To a fixed cost of 18.5 ct. add 4 ct. per cu. yd. for each 100 ft. of "lead"; and if a snatch team is required to load add 3.5 ct. more per cu. yd.

Rule III. To find the cost per cu. yd. of average earth moved with No. 3 wheel scrapers ($\frac{4}{10}$ cu. yd. load), using a snatch team, add together the following items:

$\frac{1}{20}$-hour's wages of team with driver and plowman.

$\frac{1}{12}$-hour's wages of wheeler team with driver for "lost time" loading and dumping and extra travel in turning.

$\frac{1}{18}$-hour's wages of team with driver for snatch team.

$\frac{1}{10}$-hour's wages of man loading scrapers.

$\frac{1}{20}$-hour's wages of man dumping scrapers.

$\frac{1}{24}$-hour's wages of wheeler team with driver for each 100 ft. of lead for hauling. With wages at 30 ct. for men and 15 ct. per hr. per horse, this rule becomes: To a fixed cost of 17.5 ct. per cu. yd. add 2.5 ct. for each 100 ft. of "lead."

The "lead" is the distance in a straight line from the center of the cut to the center of the fill.

For very tough clay add one-third to the above costs, while for easy sand or loam deduct one-third.

To estimate the number of cubic yards per hr. per wheeler, add together the "lost time" and the hauling time for the given "lead"; divide the sum into one. Thus, if the "lead" is 150 ft. and the wheeler is a No. 2, we have (by Rule II) $\frac{1}{6}$ hr. lost time, plus $\frac{1}{15} \times 1.5$ or $\frac{1}{10}$ hr. "lost time"; whence the total is $\frac{16}{60}$ hr. Dividing this into 1, we get $\frac{60}{16}$ or 3.7 cu. yd. per hr.

Hints on Handling Wheelers. *Engineering and Contracting,* Aug. 28, 1907, gives the following: In operating scrapers the first consideration is the plowing of the material. This seems a simple matter, consequently it is seldom done properly. If

the earth will permit, the plow should be set to cut a furrow 10 to 12 in. deep. With such a depth of well broken up dirt the scraper will be heaping full after traveling but a few feet, but if the material is not broken up well and is not plowed deep, the scraper will travel some distance over the ground without getting a good load, for the back half of the pan will not heap itself with dirt unless the loading of the scraper is done quickly and with some snap.

The furrows should be kept close together and care exercised that ridges of unplowed ground are not left between them, else the work of loading will be impeded. It is also important that the bottom of the cut should be kept level so that the scraper pan will lie flat and not be tilted to one side, thus taking a load the greater part of which will drop off on the way to the dump. It will frequently pay in stiff, heavy soils to plow the material twice, as this class of earth can be broken up in this manner so as to load the scrapers much faster and easier.

Wheel scrapers are generally made in four sizes, No. 1 being the smallest. This size is not used very extensively, because most dirt movers do not seem to appreciate their value. A snatch or snap team is not needed in operating this size scraper. One man also can load it, and two horses can pull it up an incline as easily as a drag. These facts make it as cheap to operate as a drag or slip scraper, and it carries a larger load than the largest size of the drags. The load, too, can be carried farther. This makes the unit cost of excavation much lower. For short hauls, with loads of 75 to 200 ft., a No. 1 wheeler is not only superior to a drag, but also to a larger size wheeled scraper.

In operating Nos. 2, 2½ and 3 wheeled scrapers, a snatch team is necessary to help load the scraper. Most contractors have found that in average earth, or those heavier than average, three horses in the snatch team are better than two, two horses only working well where the soils are light. The three-horse snatch team has become the usual one in most sections. Good results are obtained with it, but much better and more economical work can be done with a four-horse snatch team. Two men are generally used with a snatch team, one to hook and unhook the team to the scraper, and the other to do the driving. With four horses the same number of men are needed. The horses are hitched up in pairs. Four horses will load the scrapers not only quicker, but with a larger load. Their greatest value is in changing from one end of the cut to the other.

When loading, the scraper team should always pull in the direction in which the load is to be hauled. By doing this the

load is kept in the pan better, for in turning a loaded wheeler on the plowed ground much earth is spilled. Then, too, in narrow cuts the loaded team does not interfere with the empties, which can pass behind the snatch team, turn around, lower the pan in position for loading and pull up behind the snatch team at the proper moment. The scraper team should pull up behind the snatch team which should be backed a foot or two and hooked on.

In plowing, the two extreme ends of the row are never plowed as deep or as well as the rest of the row. Consequently in loading there is less dirt to be picked up at the ends, so the work is lighter and easier.

With a three-horse snatch team, the snatch team must be used until the last scraper is loaded at the end of the row, then time is lost by all the wheelers, while the snatch team is traveling the length of the cut to start another row. This generally means that the run of the scrapers is interfered with and one team blocks another, so that even with close attention on the part of the foreman it may be some minutes before the teams are again spaced out and moving with clocklike precision.

With a four-horse snatch team, however, this loss of time and confusion can be prevented. As the scrapers near the end of the row, and there are not two or three more loads of dirt to be picked up, two horses from the snatch team are sent to the other end of the cut and while one part of the snatch team is finishing up the old row the other part is starting a new row. The light plowing at the ends of the row makes this a quick job, and as the scrapers get into the heavy plowing of the new row, the two snatch teams have been made into one again, and the work is carried on without a break. The saving effected with a four-horse snatch team over a three-horse will generally pay for the extra horse many times over.

For most wheeled scraper work, Nos. 2 and 2½ are the best sizes to use. Contractors have adopted them for railroad, levee, wagon road, reservoir and other construction. The No. 3 is too heavy, and drags on the horses, especially in sandy or light loam. They are also too hard on a team in loading or in mounting an incline. In some special places they can be used to excellent advantage. When the load is over a good hard roadway, and the excavation is on slightly higher ground than the dump, a No. 3 is no harder on the team and is more economical than the other sizes.

In dumping a scraper one man can manipulate the scraper if the team is kept moving at a slow gait. Some contractors however, use two men on their dumps. With but little practice

a dump man can learn how to hold the pan after he has tilted it, so as to spread and level off each load as it is dumped. This is much easier to do when the load is dumped over the end of an embankment, but when dumping on a level place the dirt can be distributed in from 3 to 6 in. layers without additional work.

Scrapers are worked in "runs" according to the length of the "haul." It must be remembered that the "lead" is considered as being from the center of mass of the cut to the center of mass of the dump. The "haul" is the entire distance traveled by the scraper from pit to dump. There should always be enough scrapers in a "run" to keep the loaders and the snatch team steadily at work.

Scraper work is ideal when the lead is from 300 to 400 ft. and good work can be done up to 500 to 600 ft., but the cost quickly increases when the distance becomes greater. For this reason an extra price is needed when the leads are long. The extra price paid is termed the "overhaul price," and when it applies to scraper work the free haul should not exceed 500 ft.

It is important that wheel scrapers be operated according to a time schedule. An ideal arrangement would be to have the snatch team start at the beginning of the plowed ground. The first wheeler would be driven up to it and the snatch team backed slightly and hooked on. A second wheeler would follow the first at an interval just enough to give the first wheeler time to unhook and drive off, and so on until in its progress from beginning to end of the plowed ground, the snatch team would load all the wheelers. The length of the plowed ground preferably should be such that the snatch team can load each wheeler once without turning, and the number of wheelers used should be sufficient so that the first would be back for its second load as soon as the snatch team had returned to the beginning of the plowed ground and gotten position for loading. This ideal can not always be realized.

Reservoir Work in Mass. As giving what is probably a maximum cost we may cite the Forbes Hill Reservoir previously referred to (C. E. Saville in *Engineering News*, May 13, 1902). The material was clay-gravel or hardpan requiring two teams on a pavement plow. A snap or snatch team was used in loading the No. 3 wheelers, two men holding the scraper handles. The haul was 250 to 300 ft. "The wheel scrapers theoretically held ¾ cu. yd., but in the material here excavated only about ⅜ cu. yd. could be readily loaded automatically. Under favorable conditions each team averaged 35 cu. yd. per day (of 9 hours?) making 8 to 10 trips per hour." With labor at 15 to 17 ct. and

team (with driver) at 45 to 50 ct. per hr., the cost of excavating nearly 16,000 cu. yd. of hardpan was:

	Ct. per cu. yd.
Plowing	10.9
Scraping	22.2
Unloading and spreading carefully	7.7
Rolling embankment	3.9
Total	44.7

The cost of stripping 8,700 cu. yd. of loam and transporting to a spoil bank, (haul not given but presumably about the same,) was:

	Ct. per cu yd.
Plowing	3.4
Scraping	14.0
Unloading	0.6
Total	18.0

Bearing in mind the wages the cost was considerably above the ordinary.

Railway Work in Iowa. The following is from a paper by Mr. J. M. Brown in *Trans. of the Iowa Soc. of Eng.*, 1885: Mr. Brown's experience has led him to state that only No. 1 and No. 3 wheelers should be used. The author cannot agree with him, believing that No. 2 is the best size for all around work. The following has been abstracted from Mr. Brown's paper:

A No. 1 wheeler holds ¼ cu. yd. of earth (Iowa) on an average, and one trip in 2 to 2½ minutes is the average, where the haul is 100 ft., thus giving an output of 60 cu. yd. in 10 hr. With the following force, 1 plow, 6 wheelers, 3 loaders, 1 dumper, and 1 foreman, the cost was:

	Ct. per cu yd.
Labor, loading, dumping, etc.	4.11
Scraping (100 ft. haul)	5.83
Wear of tools	0.39
Total	10.33

With a 100-ft. haul, 6 wheelers; with a 200-ft. haul, 9 wheelers, and with a 300-ft. haul, 12 wheelers (No. 1) are required to move 360 cu. yd. in 10 hr., according to Mr. Brown, at an added cost of about 3 ct. per cu. yd. for each 100 ft. of haul. We believe this 3 ct. per 100 ft. to be erroneous because Mr. Brown has made the average speed of the team too small by failure to subtract lost time at both ends of the haul.

Mr. Brown gives the following data for No. 3 wheelers; a snatch team and two men being used to load; 8 wheelers each moving 40 cu. yd. in 10 hr. with a 400-ft. haul. With wages at 15 and 35 ct. we have:

	Ct. per cu. yd.
Plowing	1.66
Holding scraper	1.66
Dumpman	0.50
Foreman	0.70
Scraping (400-ft. haul)	7.77
Wear of tools	0.50
Total	12.79

Mr. Brown adds two wheelers for each 100 ft. of added haul, or 2 ct. per cu. yd. per 100-ft. haul, which, we repeat, is erroneous.

Wheeler Work on the Chicago Canal. Extensive data on wheel-scraper work are given in Hill's "Chicago Main Drainage Canal." Excellent papers on the same subject by A. E. Kastl and Mr. E. R. Shnable are to be found in the *Journal* of the Association of Engineering Societies, Vol. XIV, 1895. From these sources we have abstracted the following relative to costs on the Chicago Drainage Canal:

The soil moved by wheelers was a "fairly soft clayey loam," and the average haul was about 400 ft., the material being deposited in spoil banks.

On the Brighton Division, Section K, 68,300 cu. yd. were moved in 62 days, the average force being 23.8 men and 36.8 teams with drivers. There were two plows and 24 No. 3 wheelers in use, hence each plow loosened 550 cu. yd., and each wheeler moved 46.1 cu. yd. per 10-hr. day; while the average output, including snatch teams of which there appear to have been about one for every three wheelers, and including plow teams, was about 30 cu. yd. per day per team.

For Summit Division, Section E, Mr. Shnable gives the following: The haul was 400 ft. The number of men engaged is not given, but we have assumed ⅔ man per team, which is not far from right.

Stations	Average Fill, ft.	Average Cut, ft.	Total excavation, cu. yd.	Daily average, cu. yd. Per team	Daily average, cu. yd. Per whlr.	Ratio of teams Wheelers to plows	Ratio of teams Wheelers to team	Cost, ct. per cu. yd.[1]
460 to 470	12	8.0	94,879	29.8	42.2	5 1/3 –1	4 4/10–1	15.1 [2]
470 to 480	12	8.3	98.515	27.1	39.3	4 9/10–1	4 4/10–1	16.6 [2]
480 to 490	11	7.0	85,761	24.4	35.2	4 8/10–1	4 3/10–1	18.4 [2]
490 to 500	7	3.4	33,185	35.0	50.1	4 9/10–1	4 4/10–1	12.9 [3]
500 to 507	7	4.3	19,678	28.3	42.1	4 6/10–1	3 7/10–1	15.9 [4]

[1] Assuming 2/3 man per team.
Material: [2] Very stiff blue and yellow clay with a few large boulders. [3] Loamy clay. [4] Stiff clay.

The table shows that there were about five wheelers to each plow, hence each plow team must have loosened about 200 cu.

yd. in 10 hr.; the hardest section being from Sta. 480 to Sta. 490, where 168 cu. yd. was the average per plow team per day. Doubtless two teams were worked on each plow. One snatch team to every 4.4 wheelers appears to have been the average, or each snatch team loaded about 175 cu. yd. a day at a cost of 2 ct. a cu. yd.

Loading Through Traps. Wheel scrapers were used on the Chicago Drainage Canal for loading cars by dumping the earth through a platform into the cars; and similar use of wheelers for loading wagons has often been made elsewhere.

The incline approach to the platform need not rise with a less than 20% grade, and may have a width of 8 ft. instead of the 12 used on the Chicago Canal. The cost of such an incline (12 ft. wide by 120 ft. long including both approaches) is given at $100 (in 1895). It is not the first cost of the incline, but the cost of moving it that makes this method too expensive ordinarily; and the shallower the excavation the more frequent the moving of this incline. As an expedient to reduce this cost of moving the incline, the author would suggest that it be made with two wooden stringers (6-in. x 6-in.) under the sills of the bents and that these stringers which are to act like the runners of a sleigh be planed upon the bottom and rest upon cross ties or skids, placed like railroad ties, only farther apart, say 4-ft. c. to c., dressed on top and well greased. Make the flooring as light as possible, using a very small factor of safety, and make the incline in two detachable sections. Ten or a dozen teams will then readily "snake" the incline along over skids laid in advance, and it will be unnecessary to take the incline apart to move it. By study of the foregoing data it will appear that loading wagons by wheelers is cheaper than by shovels, so that if the cost of moving the incline is not great the method is a good one.

Wheel Scrapers and a Wagon Loader. The following description of the R. C. Ruthaven (Buffalo, N. Y.) wagon loader is from *Engineering News*, Apr. 23, 1896. In the operation of this device wheel scrapers were used, dumping on a platform 7 x 9 ft., in size, 2½-yd. loads were dumped and then the platform was tilted. The operation required 7 sec. to throw the earth in the hopper. From this hopper it was raised by a bucket elevator, having 22 buckets of 2 cu. ft. capacity. This discharged into a bin at the rate of 100 buckets per min. The engine was located beneath the buckets and it also tilted the platform by means of a friction attachment. The machine was mounted on wheels and was 7 x 20 ft. in size exclusive of the tilting platform.

When working in stiff clay 35 to 40 wagons holding 2 cu. yd.

each were loaded per hr. The saving on street work was 10 ct. per cu. yd. The force required and their wages was as follows. Foreman, $3; engineman, $3; fireman, $1.50; two men dumping scrapers, $3; two men loading wagons, $3; one man cleaning up, $1.50; three men loading scrapers, $4.50; five scraper teams and drivers, $18.75; one watchman, $1.50; one water boy, $1.00; two plow teams and drivers, $8; two plow men, $3.50; two men on wagon dumps, $3; ½ ton of coal, $2; total per day, $57. Some 500 to 800 cu. yd. were loaded per 10-hr. day at a cost of 7.1 to 11.4 ct. per cu. yd.

Wheeler Work Across a Swamp. *Engineering and Contracting,* Sept. 4, 1907, gives the following:

The following is an example of the cost of scraper work done by one of the editors of this journal on the grade of a new railroad. There were 2,000 cu. yd. in the cut, the "lead" being 700 ft. The work was done in the fall of the year, the weather conditions being very favorable. The material consisted of light red clay and sandy loam, turning into sand in the bottom of the cut. A four-horse plow team with two men was used in plowing at first, but when the sand was struck a three-horse plow team was used. The snatch team, which at first had three horses in it, was also changed to two when the sand was encountered.

The embankment was made over a tide-water marsh that in many places would not support a man. In these spots brush was put down, and the embankment was built in layers. The first layer was made by shoveling the dirt ahead of the wheelers. This extra work made it necessary to have four men on the dump, which accounts for the extra cost of dumping.

Two men were used to load the scrapers, which were No. 2½ wheelers holding ⅓ cu. yd. place measurement. As in many sections only one man is employed to load the scrapers, the cost in this example is doubled.

The teams were all hired, with no pace-makers owned by the contractors doing the work. The foreman consequently had but little control over the drivers, who, for one reason and another, lost time.

One side of the cut was a bluff about 15 ft. high, against which the tidewater washed. The teams could neither plow nor scrape this side of the cut down, so a gang of extra men under a foreman pulled this material down with pick and shovel, moving just enough of it so the scrapers could pick it up. It will be noticed that distributing this cost over the whole yardage moved, it amounted to 7.2 ct. per cu. yd.

The wages paid for a 10-hr. day were:

Foreman	$3.00
Extra foreman	2.50
Scraper team and driver	4.75
4-horse plow team and 2 men	9.20
3-horse snatch team and 1 man	6.00
3-horse plow team and 2 men	7.50
2-horse snatch team and 1 man	4.60
Loaders	1.60
Laborers	1.50
Water boy	1.00

The foremen were paid for every working day in the week whether it was possible to work the teams or not. The rest of the forces were only paid for the actual time they made. An average of seven scrapers were worked each day.

The entire cost of the work was:

Foreman, 13 9/10 days	$ 41.70
Scrapers, 88 3/10 days	419.42
4-horse plowing, 8 days	78.20
3-horse plowing, 3 7/10 days	27.75
3-horse snatch, 8½ days	43.00
2-horse snatch, 3 7/10 days	17.02
Loaders, 24 4/10 days	39.04
Dumpers, 43 3/10 days	64.95
Water boy, 3½ days	3.50
Total	$734.58
Extra men pulling down bank:	
Foreman, 4½ days	$ 11.25
Extra men, 88 days	132.00
Grand total cost	$877.83

This gives us a cost per cu. yd. as follows:

Forèman	$0.02
Scrapers	.21
Plowing	.053
Snatching, .03; loaders, .02	.05
Dumping	.033
Water boy	.001
Total scraper work	$0.367
Tearing down bank:	
Foreman	$0.006
Extra men	.066
Total	$0.072
Grand total per cu. yd.	$0.439

An analysis of the cost gives us the following information: A scraper team traveled 6 miles per day. They should have covered a much greater distance than this.

The plow team loosened 164 cu. yd. per day. This was all that was needed, but much more work could have been done by this team. The snatch team, of course, loaded the same amount.

They, too, could have handled more yardage, serving the same number of scrapers.

The average yardage per scraper was 23, while the average yardage for all teams engaged was 15.5.

Four Examples of Wheeler Work on Railways. Four examples of cost of wheel scraper work are given in *Engineering and Contracting*, Sept. 25, 1907. They are all work done in grading railroads. The wages paid for a 10-hr. day were:

Foreman	$3.00
Scraper team and driver	4.75
4-horse plow team and 2 men	9.20
3-horse snatch team and 1 man	6.00
Loaders	1.60
Dumpmen	1.50
Water boy	1.00

The teams were hired, and the fact that work was plentiful in that section of the country made the teamsters very independent, which helps to account for some of the high cost.

A four-horse plow team was used to loosen the dirt, and a three-horse snatch team was used in loading the scrapers. The wheelers were No. 2½, holding ⅛ cu. yd. place measurement. Two men were used to load the scrapers, which resulted in quicker loading than where only one man was used. Two men also dumped the scraper, except in Example No. 1 There was no need for this, except that a man could not be made to dump the scrapers without help. This of course doubled the cost of dumping. All the work was done in the fall of the year, the weather being very good for grading work.

Example I. The material in this case was a sandy loam, easily plowed and scraped, so as to make a heaping scraper load. The lead was 260 ft., the distance traveled on each trip by a team being 600 ft. This made a total distance per day for scraper of about 12 miles. The cost was as follows:

	Per cu. yd.
Foreman	$0.017
Scrapers	.138
Plowing	.052
Snatching	.034
Loaders	.018
Dumping	.008
Water boy	.006
Total	$0.273

The average yardage moved per day for a scraper was 34, while per team employed it was 21.

Example II. The material on this job was a good clay. Five scrapers were worked in a gang in this example as well as in Example I. The lead was 300 ft., while the average distance

traveled to the dump and back was about 700 ft., which meant a total distance covered each day by a scraper team was about 12 miles. The cost was as follows:

	Per cu. yd.
Foreman	$0.019
Scrapers	.158
Plowing	.057
Snatching	.037
Loaders	.020
Dumping	.016
Water boy	.004
Total	$0.311

The average yardage moved per scraper per day was 30 while per team employed it was 19.

Example III. The material in this cut was wet clay, made so by some heavy rains and springs that were struck in the ground. The lead was 400 ft., while the distance traveled on each trip was 1,000 ft., making a total distance traveled per scraper per day of 12½ miles. The dump was on marshy land which made necessary an extra laborer on the dump who shoveled dirt ahead of the teams. The cost was as follows:

	Per cu. yd.
Foreman	$0.026
Scrapers	.216
Plowing	.080
Snatching	.052
Loaders	.028
Dumping	.039
Water boy	.009
Total	$0.450

The number of wheelers worked in a gang was five. The average yardage moved by each scraper was 22, while that per team was 13.

Example IV. This material was a fine sand, into which the wheels sank so the scraper bowls dragged on the ground. Six scrapers worked in a gang. The lead was 500 ft., the average distance traveled going to the dump and returning being 1,000 ft., making the distance covered per day for scraper 12½ miles. The cost was:

	Per cu. yd.
Foreman	$0.024
Scrapers	.222
Plowing	.073
Snatching	.050
Loaders	.026
Dumping	.027
Water boy	.008
Total	$0.430

The average yardage moved per scraper was 21½; per team it was 13.

The plow teams loosened in the four examples respectively 170, 150, 115 and 125 cu. yd. This did not keep them busy during the day, as they could have readily loosened twice the amount they did. The snatch team could also have loaded a greater yardage. This shows that there were not enough scrapers worked in a gang.

The yardage moved by a scraper as the haul is increased was as follows:

	Cu. yd.
260 ft. lead	34
300 ft. lead	30
400 ft. lead	22
500 ft. lead	21½

It will be noticed that in all cases a scraper team traveled between 12 and 12½ miles per day. It could have been possible to have covered a greater distance.

Wheel Scraper Work on a Railroad. *Engineering and Contracting*, Jan. 22, 1908, gives the following:

The work was done on a railroad, in one cut, the material being hauled two ways. In the cut there were 2,453 cu. yd., and 1,320 cu. yd. were hauled one way to an embankment, the average "lead" being 260 ft., making a run of about 620 ft. for a trip to the dump and back. A four-horse plow team with two men and a snatch team of two horses and a driver were used. Two men manipulated the bar and catch in loading the scrapers. One man did the dumping. The cost of this was:

Foreman, 7½ days at $3	$ 22.50
Scrapers, 38 days at $4.75	180.50
Plowing, 7½ days at $9.20	69.00
Snatching, 7½ days at $4.75	35.62
Loading, 15 days at $1.60	24.00
Dumping	0.016
Water boy, 7½ days at $1	7.50
Men, 2 days at $1.50	3.00
Total	$353.37

The last two men were engaged in cutting down the slopes and dressing them. The cost per cubic yard for each item was as follows:

Foreman	$0.017
Scrapers	0.137
Plowing	0.052
Snatching	0.027
Loading	0.018
Dumping, 7½ days at $1.50	11.25
Water boy	0.006
Sloping	0.002
Total per cu. yd.	$0.267

Each scraper team traveled about 12 miles per day. The scrapers were Nos. 2½ and held ⅛ cu. yd. place measurement. The average yardage moved per scraper-day was 34, while the average per team worked was 21.

From the other end of the cut 1,133 cu. yd. were excavated, and moved an average distance of 400 ft. On the 260 ft. "lead" five scrapers were worked, but with the longer haul another scraper was added. As the embankment was across a marsh of very soft material, two men were needed on the dump to help dump and handle the material. More men were put at work on the slopes so as to have them done when the cut was finished. The cost of this end of the cut was:

Foreman, 6 days at $3	$ 18.00
Scrapers, 38 days at $4.75	180.50
Plowing, 6 days at $9.20	55.20
Snatching 6 days at $4.75	28.50
Loading, 12 days at $1.60	19.20
Dumping, 12 days at $1.50	18.00
Water boy, 6 days at $1	6.00
Sloping, 30 days at $1.50	45.00
Total	$370.40

The cost per cubic yard was as follows:

Foreman	$0.016
Scrapers	0.160
Plowing	0.048
Snatching	0.025
Loading	0.017
Dumping	0.006
Water boy	0.005
Sloping	0.040
Total per cu. yd.	$0.327

Each scraper traveled 15 miles per day, and hauled 30 cu. yd. The average moved per team worked was 20 cu. yd.

For the entire cut of 2,453 cu. yd. the average cost was $0.295 per cu. yd. The average amount moved per scraper-day was 33.5 cu. yd. for an average "lead" of 325 ft.

The Cost of Scraper Work in Freezing Weather is described in *Engineering and Contracting*, Feb. 12, 1908. This work was done during the early part of the winter before the heavy snows fell, and while the thermometer was below the freezing point during most of the day, and at night frequently registered as low as zero. The contractor had one scraper gang at work and was anxious to keep his teams going as late in the season as possible, as he had a large amount of earthwork that would have to be done during the following summer.

The following wages were paid for a 10-hr. day:

Foreman	$3.00
Laborers	1.50
Teams, 1 driver, 2 horses	3.50

The material could be classed as "average earth" as a 2-horse railroad plow would loosen it, and keep enough ground plowed for the scraper gang. Owing to the ground freezing, 4 horses had to be used on the plow, and plowing had to be done both day and night, or else the ground became so hard it could not be broken up. Places that were not plowed continually did freeze so hard that work had to be abandoned there until the following spring.

No. 3 Western wheelers with gates on them were used. The average "lead" was 250 ft., the material being carried in one direction only. Five scrapers were worked in the run, each scraper averaging 36 cu. yd. per day. As each scraper carried about ½ cu. yd., place measurement, this meant that the teams traveled about 9 miles per day. One man loaded the scraper, with the help of a 2-horse snatch team, the driver of this team hitching them to the scraper and unhitching them, as well as driving the team.

The cost per cubic yard for the work was as follows:

Foreman	$0.017
Scrapers	0.097
Plowing	0.094
Loading	0.008
Snatching	0.019
Dumping	0.008
Extra men	0.016
Total per cu. yd.	$0.259

The two extra men were used to load the large frozen clods on top of the scraper, after it was loaded, and as it was about to pull away from behind the snatch team. One man stood at each side of the scraper, as it was being loaded with several large clods in his arms ready to throw them on, as the wheelers were loaded. If these clods became very plentiful at any particular place, these men would load several scrapers entirely with clods, by hand, and thus have them carried out of the cut. They did more of this work in the fore part of the day, as during the night a great many clods were made in the plowing. These men also kept up a wood fire at which the men could warm themselves from time to time.

The cost of plowing was high, as plowing was done with 4 horses both day and night, as previously stated. If this had not been necessary the plowing could have been done for less than 3 ct. per cu. yd. Of the total cost per cu. yd., at least 8 ct. can

be charged directly to the cold weather, and 2 or 3 ct. of indirect charges can also be accounted for in the same way, as in good weather this scraper work only cost the contractor, including general expenses, 15 or 16 ct. per cu. yd.

Cost of Wheeler Grading in Winter. *Engineering and Contracting*, Feb. 26, 1908, gives the following:

In grading a railroad a section of a wagon road had to be built, and in order to carry on the railroad work the wagon road had to be graded during the winter months. The road was 2,800 ft. long and 30 ft. wide in the cuts, with a ditch on either side, 1 ft. deep, 1 ft. wide on the bottom, and 3 ft. across the top. The embankment was 26 ft. wide. There were 3,936 cu. yd. of excavation made from the cuts and borrow pits. The greatest depth of excavation was about 5 ft.; it averaged, in most places, about 3 ft.

The work was commenced during the last week of January, when the weather was fairly good, and the lightest grading work was done before the worst weather set in. A 10-hr. day was worked, the following wages being paid:

Foremen	$2.50 and $ 3.00
Scraper team	4.75
Plow team, 4 horses and 2 men	9.20
Snatch team, 3 horses and driver	6.00
Loaders	1.60
Laborers	1.50
Wagon teams	4.75
Road machine, 8 horses and 3 men	17.50

Two scraper gangs worked during January, and 1,194 cu. yd. were moved in 3 days. The cost of this was:

Foremen, 6 days at $3	$ 18.00
Scrapers, 45 days at $4.75	213.75
Plowing, 3 days at $9.20	27.60
Snatch team, 6 days at $6	36.00
Loaders, 12 days at $1.60	19.20
Dumping, 12 days at $1.50	18.00
Total	$332.55

The average "lead" on this yardage was 300 ft. The cost per cu. yd. for each item was as follows:

Foremen	$0.015
Scrapers	0.179
Plowing	0.023
Snatching	0.030
Loading	0.016
Dumping	0.015
Total	$0.278

With the wages paid, and for scraper work in January, this was a reasonable cost. The cost of plowing was low, about half

of what it would have been had two plows been used, but one plow team did the loosening for the two gangs. Each scraper moved 26½ cu. yd. per day.

While this work was going on, a foreman and crew of men were laying some 12-in. terra cotta drain pipes across the roadbed. Three such pipes were laid, aggregating 123 lin. ft., the work including the ditches for them, as well as some small details to take the water to and away from them. The cost of this work was:

Foreman, 1 day	$ 2.50
Laborers, 14½ days	21.75
Total	$24.25

This made a cost per lin. ft. of pipe of the following:

Foreman	$0.020
Laborers	0.175
Total	$0.195

The work was finished during February, but for 10 days of the 17 worked it was bitter cold and light falls of snow occurred. The ground froze to the depth of a foot and the work was more expensive than that done in January. One scraper gang worked, the cost of it being as follows:

Foreman, 16.8 days	$ 50.40
Scrapers, 131.4 days	624.15
Plowing, 16.8 days	154.56
Snatch team, 16.8 days	100.80
Loaders, 33.6 days	53.76
Dumps, 33.6 days	50.40
Total	$1,034.07

The yardage moved during this time was 2,539, the average "lead" being 350 ft. Each scraper moved about 19 cu. yd. per day. The cost per cu. yd. for each item was:

Foreman	$0.019
Scrapers	0.245
Plowing	0.060
Snatching	0.021
Dumping	0.020
Total	$0.405

In addition to this cost, the ground for a number of days had to be thawed, and two days of the coldest weather the teams could not work. Wood was used to thaw the ground, the wood being cut on the right of way, thus saving the price of stumpage to the contractor. It was hauled in dump wagons; each wagon hauled about ½ a cord per load, and made four loads per day, making a total of 2 cords per wagon-day. A crew of men cut the wood

and loaded it on the wagons. Two men built the fires and maintained them. In all about 28 cords of wood were used for the thawing. The fires were built in long windrows, and, as soon as the ground was somewhat thawed, the ashes of the fires were shoveled to one side, and a fire built up in another windrow. While this was burning up, a four-horse plow team with a pick pointed rooter plow, broke up the ground that had been thawed. This material broke up into clods which were hard to load into the scrapers. The plow point was broken frequently, and an extra one was kept in the tool box to replace it.

After the foot of frost was loosened and excavated, the plowing was done by a heavy railroad plow. At night, before stopping work, the entire excavation was plowed over nearly a foot deep; this prevented the ground from freezing so solid during the night that the rooter plow could not loosen it the next morning.

The cost of cutting and hauling the wood, and maintaining the fires was:

Wagons, 14 days	$66.50
Laborers, 21 days	31.50
Total	$98.00

This cost must be added to the other. Distributed over the total yardage moved during the month this makes an additional cost of 3.8 ct., giving a total cost of 44.3 ct. per cu. yd. Naturally, the extra cost owing to the frozen ground is not covered by this one item of 3.8 ct., for a comparison of the February itemized cost with that of January shows a difference of 12.7 ct. The cost of plowing is more than double that of January, owing to a great extent to the fact that during February the plow loosened ground for the one gang of scrapers only, while during January it worked for two gangs. The haul in February had been increased by 50 ft. Of the total difference in cost at least 13 ct. can be directly charged to the cold weather and freezing ground.

Of the ground actually thawed by the wood fires there were about 1,511 sq. yd. The cost of thawing this was about 6½ ct. per sq. yd. As the frost penetrated the ground about one foot this meant that 503 cu. yd. of earth had to be thawed, at a cost of 19 ct. per cu. yd. The material was a red sandy clay. During the rest of the time, after the freeze, it was very muddy and difficult to handle.

Fig. 11 shows a cross section of the road as it was actually built. The trimming and dressing outside of the ditches were done by a road machine immediately after the scrapers finished the work. Owing to the winter weather eight horses had to be

used on the machine, and this meant an extra driver. The mud made the work difficult. The most of this was $43.75 for 2½ days' work. As the banks were 26 ft. wide, the total area dressed by the machine was 7,467 sq. yd., which gave a cost for trim-

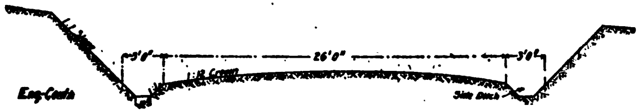

Fig. 11. Cross Section of Road as Built.

ming and dressing with the machine of 0.6 ct. per sq. yd. This cost distributed over the yardage moved, namely, 3,936 cu. yd., made 1.1 ct. per cu. yd.

After the weather had settled in the spring and the ground had dried, a force of men under a foreman was put to work cutting the ditches in the cuts. The cost of this was:

Foreman, 4 days	$10.00
Laborers, 37 days	55.00
Total	$65.50

From the ditches, 213 cu. yd. were excavated, which meant a cost of 30.7 ct. per. cu. yd., and as there were 3,075 lin. ft. of ditch the cost per lineal foot was 2.1 ct. Distributed over the total yardage excavated, it gave a cost of 1.7 ct., making the total cost of trimming and dressing per cu. yd. as follows:

Work with road machine	1.1 ct.
Work by hand	1.7 ct.
Total per cu. yd.	2.8 ct.

This would also have increased the cost per sq. yd. more than 1 ct. If the cross section of the road had been as shown in Fig. 12, the road machine would have done all the dressing and trimming and the $65.50 could have been saved. This clearly demonstrates that the more economical design is that illustrated in Fig. 12. It must be remembered that the drainage can be amply cared for by the crown and the extra height of the metal.

The road was given a metal coat, supposedly 6 in. thick, 16 ft.

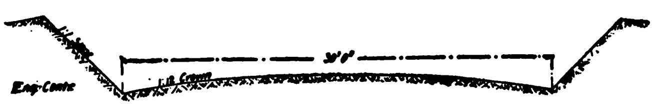

Fig. 12. Cross Section of Road as It Should Have Been Built.

wide, of oyster shells. On account of the mud in some places the shells were much thicker. These shells, 12,300 bushels, were delivered at a wharf near by on board of large scows, and were hauled in market wagons an average distance of 4,500 ft. The shells were loaded by scoop shovels, and the wagons had two holes cut in the bottoms. This allowed the shells to be dumped out of the end of the wagon and through the holes. One man with a large rake, a fork and a shovel spread the shells. The cost of this work was:

Foreman, 5.8 days	$ 14.50
Wagons, 45.3 days	215.17
Men loading, 17.4 days	26.10
Man spreading, 5.8 days	8.70
Total	$264.47

This made a cost for hauling and spreading of 11.5 ct. per bushel. The shells were only put on about 2,300 lin. ft. of the road, giving about 4,100 sq. yd. The shells cost 7 ct. per bushel delivered at the wharf. This gave a cost per sq. yd. of shells in place as follows:

Shells	21 ct.
Labor and hauling	11.5 ct.
Total	32.5 ct.

The shells were not rolled, but they were first placed on the road nearest the wharf, and the loaded and empty wagons hauled over them. As any holes developed, additional shells were placed in them.

The total cost of the work was as follows:

Scraper work	$1,366.62
Labor of laying drain pipe	24.25
123 lin. ft. 12 in. T. C. pipe at 30 ct.	36.90
Thawing ground	98.00
Road machine work	43.75
Ditching in cuts	65.50
12,300 bu. shells at 7 ct.	861.00
Labor of placing shells	264.47
Total	$2,760.49

All of this work could have been done cheaper if it had not been the dead of winter. Even the shells could have been bought for 4 or 5 ct. per bushel during the summer.

Comparison of Cost of Wheel and Drag Scraper Work in Mississippi. Cost data on the enlarging of a log pond are given by M. E. Allen in *Engineering and Contracting*, March 4, 1908. The work required the excavation of the end bank of an old pond and the extension of the side banks a distance of 350 ft. The area of the pond was increased from one to four acres.

As the site was full of pine, oak and gum stumps of considerable size, and extremely difficult to dislodge except with dynamite, it was decided to raise the old banks 1 ft., giving a depth of 8 ft. where the logs are unloaded and a minimum depth of 3 ft. 6 in. in the far end of the pond over the 3-acre addition. In carrying out this plan it was decided that all stumps be sawed off at the ground, and that only enough dirt be excavated from the new pond site to build the banks, and that dirt be borrowed from the most advantageous places.

The cross sections showed that the banks would require 2,028 cu. yd. It was estimated that by doing the excavation by company's forces and teams the cost would not exceed $400.

There were on hand four 1/3 cu. yd. wheel scrapers and two "slips." As there were 100 lin. ft. of bank so situated that dirt could be obtained right at hand and without plowing it was decided to let the slips handle the 162 cu. yd., and compare the costs for slips working under most favorable conditions and wheelers under average conditions. The two slips finished the 162 cu. yd. in 4.5 days, and, as the unit cost was found to exceed that of the wheelers under less favorable conditions, their use was discontinued.

The total cost of all the grading with slips and with wheelers was as follows:

Foreman, 17.5 days at $3	$ 52.50
Labor, 165.9 days at $1	165.90
Teams, 145 days at $0.77	111.65
Total	$330.05

The cost per cu. yd. was 16.3 ct.

The cost under teams includes only the actual cost of feed used, for the teams were all company property. The drivers are listed under labor.

To arrive at a comparison for wheeler and slip work, 33% of the foreman's time was charged to the latter during the first 4.5 days that the slips were used. This gave a cost for the slip work as follows:

1 foreman, 4.5 days at (1/3 of $3) $1	$ 4.50
4 men, 4.5 days at $1	18.00
2 teams, 4.5 days at 0.77	6.93
Total	$29.43

This gave a cost per cu. yd. of 18.2 ct.

The cost of the wheel scraper work alone was 16.1 ct. per cu. yd.

The average number of cu. yd. handled per scraper-day was 29.6. The average lead was 150 ft.

Nine Examples of the Cost of Wheel Scraper Work. (See *Engineering and Contracting*, July 8, 1908.) Some of these examples have already been given but their costs are repeated here for comparison.

The cost records were kept in great detail. In every case the work done was in grading a railroad bed and No. 2½ wheelers were used.

The wages paid for a 10-hr. day were as follows:

Foreman	$3.00
Scraper team and driver	4.75
4-horse plow team and 2 men	9.20
3-horse snatch team and 1 man	6.00
Loaders	1.60
Dump men	1.50
Water boy	1.00

The grading was done in the fall of the year with good weather prevailing. The material excavated was red clay subsoil with some sand mixed with it. The teams were hired, the contractor furnishing the scrapers, plows, etc.

Table 1 gives the length of the lead in feet, the lead being the distance in a straight line from the center of mass in the excavation to the center of mass of the embankment. The length of the haul exceeds the lead, the haul being the average distance traveled by the scraper in going to and from the dump, including the distance traveled in turning at both ends of the haul.

A crew consisted of a foreman, a 4-horse plow, a 3-horse snatch team, 2 loaders, 2 dump men, a water boy and the given number of wheeled scrapers.

In Table 2 the cost of the work is given, showing the cost of each item separately.

These costs do not include any allowance for plant or maintenance and repairs to plant.

These records are not given either as ideal records or as economical examples of scraper work, but may be of benefit to those interested in scraper work.

It would seem that the distance covered per day by each scraper in the first two examples was much less than it should have been, as in other examples each scraper team covered more than 16 miles. Under these circumstances, if the foreman did not allow his men and teams to loaf, time must have been wasted by the scrapers in waiting to be loaded, thus showing that too many scrapers were worked in the run. This is evident for another reason. With a haul of 600 ft., with a team traveling at the rate of 200 ft. per min., which is not excessive even over such ground as a scraper is used upon, the scraper should make the round trip in 3 min. It takes not over a minute to

load a No. 2½ wheeled scraper under fair conditions, hence from the time the scraper leaves the cut to its return only 3 scrapers have been loaded, with the result that the scraper must wait a minute while the fifth scraper is being loaded.

From this it would seem that for a 260 ft. lead, 4 scrapers should be used instead of 5. This would have meant that the expenses of the gang would have been reduced $4.75 and each scraper worked would have moved a greater yardage. Theoretically the time wasted in waiting to be loaded would have allowed of 30 additional trips of a scraper during the day, which would have meant an increase of 10 cu. yd. per day per scraper. The increase might have been a little more, as the 5 scrapers set a lazy pace, while the 4 scrapers coming to the snatch team regularly would have been the cue for the whole gang to have worked with greater snap and vim. This increased yardage would have meant that the gang would have averaged 176 cu. yd. per day, thus decreasing all the cost items somewhat.

The time lost waiting to be loaded in using 5 scrapers on a 300 ft. lead, where the haul amounted to 725 ft., is not as much as on the 260 ft. lead, the lost time being but ⅜ of a min. The cut or excavation, instead of being worked as a single piece of work with a lead of 300 ft. and a haul of 725, should be divided into two pieces of work, so that one piece would have an increased haul over the 725 ft. and suited for a run of 5 scrapers, while the other piece would have a decreased haul, one suited to 4 scrapers. In this manner, the scrapers employed could be worked all the time, and the maximum output obtained and the "hauls equalized," as the contractors express it.

From example No. 3 it would seem that 6 scrapers were about the correct number for a 1,000 ft. haul, but in example No. 4 the snatch team had to wait on the scrapers. This was likewise the case with examples Nos. 5 and 6. In example No. 7 too many scrapers were worked in the gang, and the contrast between the number used with an 800 ft. and 900 ft. lead is very striking.

Again in examples Nos. 8 and 9 not enough scrapers were used.

It will be noticed that for the shorter hauls the increased cost due to adding 100 ft. to the lead, with wages as paid for this work, is about 1 ct. per cu. yd. When the leads are longer than 500 or 600 ft. the costs increased much more than 1 ct. The ordinary price paid for overhaul in many sections of the country in the past has been 1 ct. per cu. yd. for each 100 ft. of overhaul. For short free haul with low wages there may be, at times, a small profit at this price, but under most circumstances 1 ct. per cu. yd. per 100 ft. will hardly cover the cost of wheel scraper overhaul, especially if the free haul is 1,000 ft.

TABLE I

Item No. Headings	Ex. No. 1	Ex. No. 2	Ex. No. 3	Ex. No. 4	Ex. No. 5	Ex. No. 6	Ex. No. 7	Ex. No. 8	Ex. No. 9
1. Lead in ft.	260	300	400	500	700	800	900	1,300	1,400
2. Haul in ft.	600	725	1,000	1,100	1,450	1,650	1,900	2,700	2,900
3. Distance traveled in miles	12	13	16.5	17.5	19	19.5	17	18	19
4. Cu. yd. moved per scraper	34	32	29	28	23	20.8	16	11.7	11.5
5. Cu. yd. moved per team	21	20	19	18	15.5	14	12	9	9
6. No. scrapers in gang	5	5	6	6	7	7	12	12	12
7. Av. cu. yd. moved per day	170	160	174	168	161	146	192	141	138

TABLE II

Headings.	Ex. No. 1	Ex. No. 2	Ex. No. 3	Ex. No. 4	Ex. No. 5	Ex. No. 6	Ex. No. 7	Ex. No. 8	Ex. No. 9
Foreman	$0.017	$0.017	$0.016	$0.017	$0.018	$0.020	$0.015	$0.021	$0.023
Scraper	0.138	0.149	0.164	0.170	0.210	0.228	0.293	0.407	0.410
Plowing	0.052	0.052	0.050	0.051	0.056	0.062	0.046	0.065	0.070
Snatching	0.034	0.034	0.033	0.034	0.037	0.040	0.030	0.043	0.046
Loading	0.018	0.018	0.017	0.018	0.020	0.021	0.016	0.023	0.024
Dumping	0.016	0.017	0.016	0.017	0.018	0.020	0.015	0.021	0.023
Water boy	0.006	0.006	0.005	0.006	0.006	0.006	0.005	0.007	0.007
	$0.281	$0.293	$0.301	$0.313	$0.365	$0.397	$0.420	$0.588	$0.603

Contractors should give this matter some study and see to it that their bids are such as net them a profit on each item. The writer knew of a contractor who bid an overhaul price of 2½ ct., with a free haul of 1,500 ft., and even at this price there was no profit in the overhaul during the winter months.

The cost per cubic yard for plowing in Table 2 is high, when one takes into consideration that, at the wages paid, earth should be loosened for about 3 ct., but this high cost is caused by the fact that the plow team was kept in the cut during the whole day, whether it was working or not. According to the nine examples, the plow loosened on an average 160 cu. yd. per day. A 4-horse plow can easily loosen from 300 to 400 cu. yd. per day, say 350 cu. yd. This would mean considerably less than 3 ct. per cu. yd. This shows the necessity of working two scraper gangs, wherever possible, close enough together so that one plow team can serve the two gangs.

Two men were used to load the scrapers. For a small wheel scraper, one man is sufficient, and it is possible for one man to load a No. 2½ or No. 3 wheeler, but 2 men will do the work more efficiently, and they are needed when a 4-horse snatch team is used. Under most circumstances a 4-horse snatch team will do more economical work than a 3-horse snatch team.

In the examples here given two men were used to dump the scrapers. This is not necessary, as one man can easily learn to dump even the large size wheelers without aid, and the only reason two men were used was on account of the labor market. Men were difficult to obtain, and to detail only one man to a dump meant a strike among the laborers. If only one man had been used the cost of dumping given would have been cut in half.

It will be noticed that the cost of the items of the work, other than the actual scraper cost, amount to from 30 to 60% of the total cost, thus showing that the scraper must move from 50 to 100% more earth than needed to show a profit on each scraper's work. Only the best horses or mules should be employed, and good care must be taken of them, or else they will soon grow stale in their work, and the output will rapidly decrease.

Economic Handling of Earth by Wheel and Fresno Scrapers. Richard T. Dana in *Engineering and Contracting*, June 3, 1914, discusses this matter at great length.

It has been the experience of the writer that a majority of contractors east of the Alleghenies are unfamiliar with the relative advantages of the different kinds of scraper and do not possess the data necessary to determine for the particular conditions of their work which style and size should be most economic. A contractor who has found wheel scrapers very success-

DATA USED IN CALCULATING COST CURVES FOR WHEEL SCRAPERS IN LOAM AND CLAYEY LOAM

C	896 ct.	D	Varies.
w	Varies.	S	209 ft. min.
l	1.54 min.	K	1.1.
W	600 min.	1/K	0.91.

Value for C for 5-scraper gang determined as follows:

10 mules at $1.75	$17.50
5 drivers at $1.95	9.75
1 loader at $2.25	2.25
1 dumpman at $1.75	1.75
1 3-mule snatch at $5.25	5.25
1 3-mule snatch driver at $2.25	2.25
1 D. R. at 3% per month	1.07
Foreman at $4	4.00
Water boy at $1	1.00
Total	$44.82
Per scraper	8.96

Value of scraper	$48.00
Value of harness	50.00

$$R = \frac{1}{w}\left[\frac{C.\ D.\ (1 + 1/k}{S\ W} + \frac{l\ C}{W}\right] = \frac{1}{w}\left[\frac{896 \times 1.91\ D}{209 \times 600} + \frac{1.54 \times 896}{600}\right] = \frac{1}{w}\left[0.01365\ D + 2.30\right]$$

w	Costs D = 100′	500′	1,000′
.10	36.65	91.25	......
.15	24.43	60.83	106.33
.20	18.32	45.62	79.75
.25	14.66	36.50	63.80

w	Costs D = 100′	500′	1,000′
.30	12.22	30.42	53.17
.35	10.47	26.07	45.57
.40	9.16	22.81	39.87
.45	8.14	20.28	35.44

ful in a certain kind of earth is likely to be biased in favor of the wheel scraper for that kind of earth more or less regardless of the length of haul. Errors of judgment in a matter of this kind result in literally burying for all time money that ought to bring some benefit to somebody.

A careful study and analysis of scraper work was made under the direction of the writer by A. C. Haskell for the Construction Service Co. of New York, and the results are given below to enable those who have scraper work to make rapidly and conveniently those computations without which no work of this kind can economically be done.

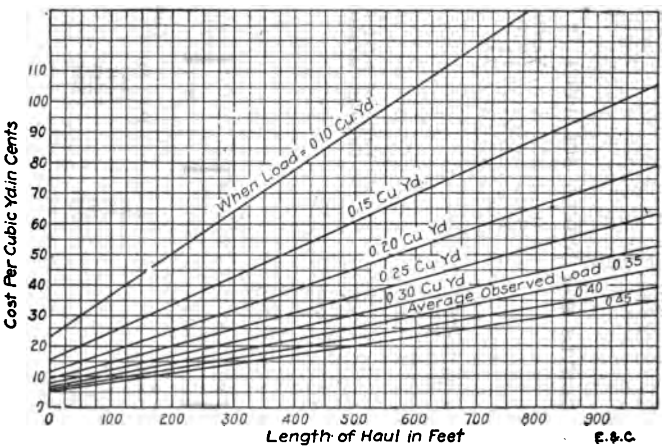

Fig. 13. Curves Showing Costs per Cubic Yard of Handling Loam and Loam Clay with Wheel Scrapers for Various Sizes of Load and Length of Haul.

The results of this analysis are summarized in Figs. 13 to 15. When Fresno scrapers are loaded from plowed ground it is easier to load when dragging across than lengthwise of the furrow. Double plowing is often economical. The dumping operation should be accomplished by a quick, sharp lift on the handle, and preferably on a down grade. When the ground is very well loosened the driver can do his own loading as well as dumping. The path to the dump must be reasonably free from obstructions, else the scrapers may dump themselves without intention on the driver's part.

General Hints on all Scraper Work. (1) Be sure to use the right kind of scraper. A Fresno with 3 mules is economical up to about 275 ft. of haul as against wheel scrapers with 2 mules, when it can load readily. Where the ground is full of roots use wheelers.

To drivers:

(2) Report any case of bad fitting harness to the foreman im-

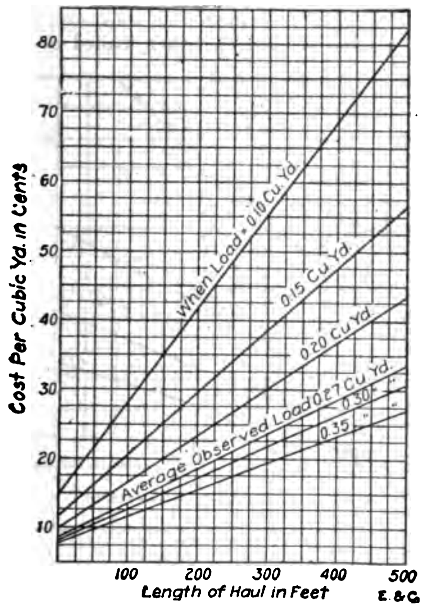

Fig. 14. Curves Showing Cost per cu. yd. of Handling Loam, Sand, etc., with Fresno Scrapers for Various Sizes of Load and Length of Haul.

mediately. Don't let the team drag you by the reins. You are supposed to be able to walk as far as a loaded team.

To foreman:

Make a personal detailed inspection of each mule's harness the first thing in the morning and at noon, and report any case of ill fitting harness to the timekeeper on his next round. Foremen will be held responsible for allowing any mule to work with badly fitting harness.

(3) See that each scraper is fully loaded. The cost of plowing is less than 1 ct. per cu. yd., which is less than the cost of letting scrapers work when only partly loaded.

(4) In loading the scraper when it is once full of earth do not let the mules try to pull it any farther and overload it. The last two seconds of drag against the dead weight of earth are mule killers.

(5) On all scraper work drivers are required to walk at all times when the scraper is loaded and they are to walk at all times with the Fresno scraper, whether loaded or empty. With

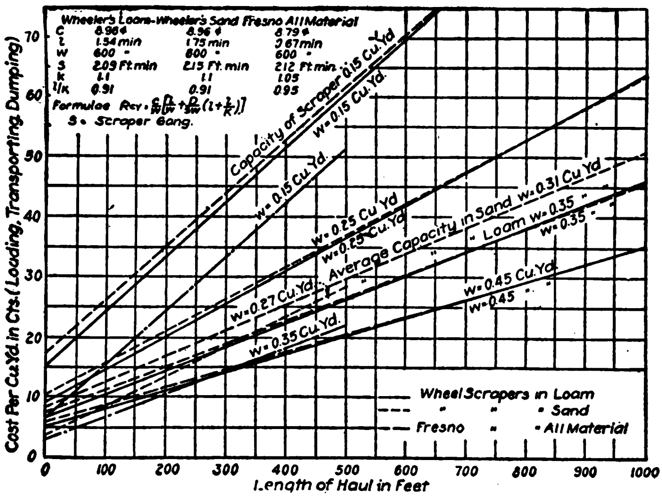

Fig. 15. Diagram Comparing Economy Up to 275 Ft. Haul of Fresno and Wheel Scrapers.

wheeler scraper work drivers should ride on the scraper when it is empty. In stepping on or off of the scraper be sure not to delay the team in any way.

(6) In dumping wheel scrapers try not to dump when the mules are on ground that is lower than the scraper, as by doing this it brings a tremendous load on the mules' necks.

(7) So direct the work that the loaded teams will have the shortest haul and the empty teams if necessary may have a much longer haul, but in no case should the empty haul be unnecessarily long. It is better to let the mule team stand still to rest than to let it cover unnecessary ground. This seems

like a simple rule, but its violation has often been observed on several different jobs.

(8) See that the scrapers are spaced as even a distance apart as possible. This will make the work lighter on the mules, easier on the drivers and will tend to avoid confusion.

(9) The loaded scraper should always have the right of way as against the unloaded scraper.

(10) Whenever a scraper gets stuck or is in any trouble don't lose any time before notifying the foreman and sending for help. The snatch team is employed for the purpose of helping the scrapers at all times and in all possible ways.

(11) Be sure not to have too few scrapers on a long haul and too many scrapers on a short haul; see that every scraper is busy all the time; see that the loader and snatch teams are busy all the time; in short, that each unit of the work is contributing its maximum effort to the accomplishment of the whole.

Costly Wheel Scraper Work in a Wet Cut. *Engineering and Contracting*, Sept. 30, 1908, gives the following:

The record of cost of making a railroad cut with wheel scrapers, given below, demonstrates how a lesson can be learned from cost keeping.

The material in the cut was a red clay with springs of water occurring in it. This, with the fact that the clay quickly absorbed the rain water and held it, made the cut a wet one. Wheel scrapers were used and a 3-horse snatch team for loading them. A 4-horse plow team loosened the dirt. The following wages were paid for a 10-hr. day:

Foreman	$3.00
Scraper team and driver	4.75
4-horse plow team and 2 men	9.20
3-horse snatch team and 1 man	6.00
Loaders	1 60
Dumpmen	1 50
Water boy	1.00

Two men loaded the No. 2½ scrapers, and one man dumped them. The lead was 700 ft., while the total distance traveled to and from the dump averaged 1,650 ft.

The cost of the work per cu. yd. was as follows:

Foreman	$0.063
Scrapers	0.500
Plowing	0.200
Snatching	0.127
Loading	0.067
Dumping	0.032
Water boy	0.021
Total per cu. yd.	$1.010

The average number of cu. yd. moved per day per scraper was 9.5, and as 10 scrapers were used on the haul, the gang moved a total yardage per day of 95 cu. yd. This gives the amount loosened by the plow. The average number of yards moved per team worked in a day was only 5.5. Each scraper team traveled about 9 miles per day.

A comparison of these with costs previously given shows at once that they are excessive. The scraper team traveled only 9 miles per day. This was caused by the wet condition of the cut, and ten scrapers each going through it 28 or 29 times a day meant cutting up the wet clay still more. Some other method of excavating the earth should have been used.

Doubletrees for Heavy Slip and Fresno Scraper Work. R. E. Post, in *Engineering and Contracting*, Mar. 6, 1912, gives the following:

In moving dirt with slips or fresnos and the accompanying work of pulling roots, dragging large rocks, etc., one of the most annoying delays is caused by the use of weak or clumsy doubletree sets.

One of the worst details is the singletree hook which pulls from the back of the singletree and which, whenever the doubletrees are used off of a tongue, cause the singletree to turn half over. Usually at the first hard pull the cast eye of the singletree ferrule breaks, or the center clip spreads. Then there is the clevice and bolt method of fastening the doubletree set to the slip. This is a good rig (although necessitating heavy doubletrees), so long as the team is on a slip, but when needed elsewhere some time is wasted unfastening and fastening the clevice. Moreover, the clevice is a poor device to which to fasten a chain or rope quickly and when a doubletree set is not in use someone usually takes the clevice and forgets to return it. The above annoyances are likely to occur many times a day where such doubletree sets are used and they provoke foremen and teamsters as well as cause considerable delay.

The factory-made doubletree sets sold under the name of lead bars are light and handy, but will not stand use on a plow, stump pulling, or other heavy work without much breakage. Further the center clip, fastening the hook to the doubletree, soon becomes loose and pulls to one end. Home-made doubletree sets made of the best woods with factory-made center clips, end straps, and hooks, are a great improvement over the lead bars, but the largest oval woods obtainable for the doubletrees will not stand all kinds of work without considerable breakage and the center step fastening the hook to the doubletree behaves the same as in the factory-made lead bars.

Fig. 16 shows a set of doubletrees that will stand the jerks of the heaviest teams, that is not too heavy, that is reasonable in cost, and that will not ordinarily be in the repair shop until worn out. The doubletree center clip in particular is a trouble saver, as whenever the wood shrinks and the clip becomes loose it can be readily tightened with the bolt. Another advantage

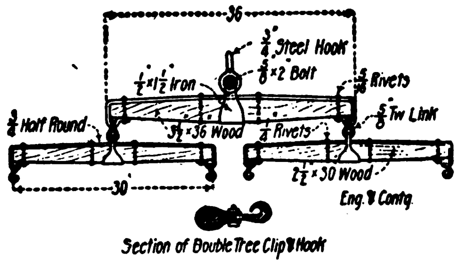

Fig. 16. Detail Drawing for Slip Doubletrees.

is in being able to replace a broken hook without a weld. In case considerable work involving pulling on a chain is to be done a special grab hook may easily be inserted or, better yet, one or two sets can be rigged with grab hooks and kept for this work.

The following is the itemized cost of one of these doubletree sets:

4 ft. 1-in. half round iron	$0.135
7 ft. ¾-in. half round iron	0.130
1 3½ x 36 in. wood	0.420
2 2½ x 36 in. wood	0.400
1 ft. ¾-in. tool steel	0.110
4 singletree hooks	0.160
16 in. ½ x 1½ in. iron	0.085
2 center clips	0.240
12 rivets	0.050
1 bolt ⅝ x 2 ins.	0.015
2½ hr. labor at 45 ct.	1.125
Total	$2.870

Methods of Arranging Doubletrees and Three-Horse Eveners. *Engineering and Contracting*, June 12, 1912, gives the following:

In making three-horse eveners little difficulty will be experienced if consideration is taken of the fact that the amount of work each horse does is in proportion to the lever arm or the portion of the doubletree given to him. In the case of three horses the third horse, or the one which works singly, should be given a leverage to make its pull equal to that of the other two.

The length of the evener, and also the lengths of the singletrees, will depend upon the size of the horses and also whether it is desired to work them close together or somewhat spread apart. For summer work the horses will stand the heat better if given plenty of room.

In Fig. 17 is shown a common three-horse evener arranged for horses of about equal weight and strength. The distances shown

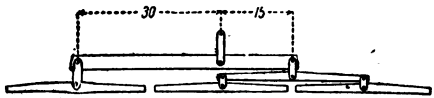

Fig. 17. Common Three-Horse Evener.

are recommended for horses of medium size and should be increased proportionately for large teams.

Sometimes it is necessary in working young animals or light horses to give them plenty of advantage by increasing the length of the lever arm. This must be done by trial, as no rule will do for all cases. The most satisfactory way is to bore a number of holes and shift the clevis until the small horse is able to carry the load the entire day without becoming more fatigued than the other horses. It is believed by some men that the amount of lever arm or advantages given to the smaller horse should be in proportion to the weight of the animal, but this is not always satisfactory because it is also necessary to take into account the physical condition of the horses. A type of evener which permits an unusually close hitch is shown by Fig. 18. These two

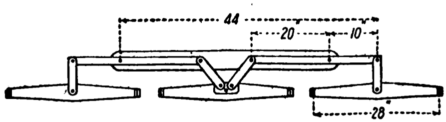

Fig. 18. Evener for Close Hitching.

eveners are recommended in the *Bulletin* of the International Harvester Co.

Effect of Bonus System on Cost of Basement Excavation. *Engineering and Contracting*, July 22, 1914, gives the following:

It is unquestionably true that most workmen will put forth extra effort when they are certain of receiving monetary return for extra performance. The following data show the results of a bonus system as applied by the Aberthaw Construction Co., of Boston, to excavation work. The work consisted of excavating the

site of a reinforced concrete building in New Haven, Conn. The building was 62 ft. wide by 400 ft long, the basement floor being about 10 ft. below the natural grade. The work was done in mid-winter. As the excavated material was to be used in bringing up to grade the depressions in other parts of the lot, the contractors decided to use wheel scrapers. In addition to the excavated earth, quantities of sand were taken out and placed in storage piles for use later in concrete. The loam and top soil were first removed by means of plows and frost wedges.

A study of the length of haul and of the number of *wheel scraper loads* per day showed that on the average 120 loads constituted a full day's work, although for the longer hauls only about 110 loads per day were made. The teamsters, when going about their work in the usual leisurely way and with no incentive for high performance, at best were hauling only 120 to 130 loads per day. The application of the bonus system changed the entire tone of the work from half-hearted endeavor to enthusiastic effort.

In starting payment for extra work each driver who had made 120 loads or more during the day was given a bonus of 50 ct. This bonus was later increased to $1 for each man who made 150 loads during the day — a mark which several reached. It was expressly stipulated that the horses should not be mistreated and that loads which were not full would not be credited on the tally board. While these instructions were well followed, it is probable that the horses were worked to their limit.

The curves of Fig 19 show the variation in quantity of excava-

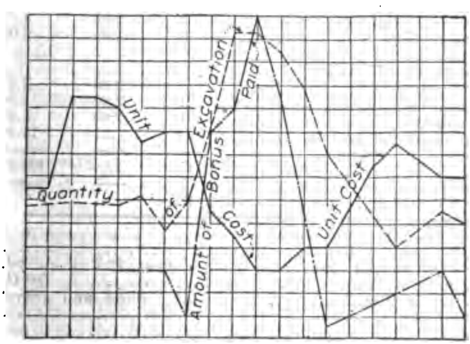

Fig. 19. Curves Showing Variation in Quantity of Excavation, Bonus Paid, and Unit Cost for Basement Excavation in New Haven, Conn.

tion, amount of bonus paid, and cost per cubic yard for excavation. No attempt has been made to give actual values as comparative values only were desired. By referring to these curves it is seen that the cost per cubic yard of excavation was lowest when the quantity of excavation and consequently the amount of bonus were highest. It will be noted that increase or decrease in cost per cubic yard of excavation is in inverse ratio to the increase or decrease of quantity of excavation and bonus paid, throughout the length of the curves. The decrease in cost from about 35 ct. per cu. yd. at the time the bonus was first applied to 25 ct. per cu. yd. and under for the peak of the excavation curve involved a saving of more than $60 per day during the period of maximum excavation.

Keeping Cost of Scraper Work so as to Show the Daily Unit Cost for Each Gang is described by W. A. Gillette in *Engineering and Contracting*, July 24, 1912:

The value of daily cost records is widely recognized but unless earth is handled in wagons or cars the difficulty of estimating quantities is such that daily records are seldom kept.

FRESNO EXCAVATION

DAILY REPORT

Date ....

Job No.................... Gang No.................

Foreman ....

Occupation	No.	Rate	Amt.
Sub-foreman	1	$3.10	$ 3.10
Fresno stock 4-up	36	1.00	36.00
Fresno drivers	9	2.00	18.00
Fresno loaders	2	2.00	4.00
Fresno dumpers	2	2.00	4.00
Plow stock 6-up	6	1.00	6.00
Plow stock up	..	....	......
Plow stock up	..	....	......
Pile drivers	1	2.25	2.25
Plow holders	1	2.00	2.00
Laborers	1	2.00	2.00
% overhead cost 29	..	....	14.40
Men	17	....	$91.75
Totals......Stock	42	....	

Sta. under construction ....

Sta. completed ....

Cu. yd. moved, 280. Cost, 32.7 ct. cu. yd.

Length of haul ....300 ft.

Kind of dirt...........................Sand and gravel

Remarks ....

....

....

....

Timekeeper.

Fig. 20. Timekeeper's Report Form for Fresno Excavation.

Mr. Gillette's method of keeping cost consisted in having the timekeeper count the loads hauled by every gang during at least two 20-min. periods, one in the forenoon and one in the afternoon. The timekeeper is provided with a saddle horse.

The timekeeper was given a statement of the estimated size of load of each kind of scraper and wagon. Thus, a No. 2½ wheeler was estimated to hold ⅛ cu. yd., measured in place. A "three-up" dump wagon was estimated to average 1¾ cu. yd.

GRADER EXCAVATION

DAILY REPORT

Date ....

Job No.................... Gang No.................

Foreman ....

Occupation	No.	Rate	Amt.
Sub-foreman	..	....	......
Excavator stock 16-up	16	$1.00	$16.00
Lead drivers	1	3.00	3.00
Push drivers	1	2.50	2.50
Machine men	1	4.00	4.00
Elevator men	1	2.50	2.50
Wagon stock 3-up	15	1.00	15.00
Dump men	1	2.50	2.50
% overhead cost 18	..	....	8.70
Men	5	....	$59.20
Totals......Stock	31	....	

Sta. under construction ....

Sta. completed ....

Cu. yd. moved, 595. Cost, 10 ct. cu. yd.

Length of haul ....300 ft.

Kind of dirt...............................Sand and gravel

Remarks ....

....

....

....

Timekeeper.

Fig. 21. Timekeeper's Report Form for Grader Excavation.

Fresnos were estimated at different capacities, according as the pull was uphill, or downhill, or level; and in some cases it might be desirable to vary the estimate, according as the haul is short or long.

The first month this plan was tried about 70,000 cu. yd. were moved and the timekeeper's estimates came out only 5% in excess of the engineer. The second month, for an equal amount of work, he was nearly 5% too low, so that for a period of two months the engineer's estimates were checked almost exactly.

By following this plan it was soon discovered that wheeler work was costing more than fresno work. Also that for hauls

of more than 150 ft. the cheapest method was to load wagons with fresnos through a trap.

This plan of intermittently timing each grading gang has the great merit of enabling the contractor to ascertain approximately his unit cost every day for every gang.

TRAP EXCAVATION

DAILY REPORT

Date ....

Job No..................... Gang No.................

Foreman ....

Occupation	No.	Rate	Amt.
Sub-foreman	1	$2.50	$ 2.50
Fresno stock 4-up	20	1.00	20.00
Fresno drivers	5	2.00	10.00
Fresno loaders	2	2.00	4.00
Fresno dumpers	1	2.00	2.00
Wagon stock 3-up	15	1.00	15.00
Wagon drivers	5	2.00	10.00
Plow stock 2-up	2	1.00	2.00
Plow stock up	..	....	......
Trap men	..	....	......
Dump men	1	2.50	2.50
Plow drivers	1	2.25	2.25
Plow holders	..	....	......
% overhead cost 25	..	....	12.45
Men	16	....	$82.70
Totals......Stock	37	....	

Sta. under construction ....

Sta. completed ....

Cu. yd. moved 730. Cost, 11.3 ct. cu. yd.

Length of haul ....300 ft.

Kind of dirt..........................Sand and gravel

Remarks ....

....

....

....

Timekeeper.

Fig. 22. Timekeeper's Report Form for Wagons Loaded by Fresnos Through a Trap.

A Four-Wheel Scraper of Large Capacity. *Engineering News*, Oct. 21, 1915, gives the following:

Recently a four-wheeled scraper of 1 cu. yd. capacity has been introduced, and has been used with success in a number of construction works. (See Figs. 26 and 27.)

A steel frame is carried by two axles, having 30-in. front wheels and 48-in. rear wheels, and its forward end is arched so as to clear the wheels and allow the machine to make a very short turn. The steel scraper bucket is 46 in. long, 45 in. wide and 25 in. deep, with a nominal capacity of 1 yd., but heavier loads

have been excavated and hauled. The rear end of the bucket is suspended by short chains attached to the sills of the frame and to the bottom corners of the bucket. The front end of the bucket has a bail pivoted to the bottom corners, with chains passing over a shaft carried above the frame. This shaft is fitted with sprocket wheels driven by chains from the axle, a clutch enabling the shaft to be thrown in or out of gear. The driver sits at the rear, where he has a good view of the work.

WHEELER EXCAVATION

DAILY REPORT

Date ....

Job No.................... Gang No................

Foreman ....

Occupation	No.	Rate	Amt.
Sub-foreman	1	$3.10	$ 3.10
Wheeler stock 2-up	20	1.00	20.00
Wheeler drivers	10	2.00	20.00
Wheeler loaders	4	2.50	10.00
Wheeler dumpers	2	2.50	5.00
Snap teams 3-up	6	1.00	6.00
Snap drivers	2	2.50	5.00
Plow stock 4-up	4	1.00	4.00
Plow stock up	..	....	......
Plow stock up	..	....	......
Plow drivers	1	2.00	2.00
Plow holders	1	2.00	2.00
% overhead cost 28	..	....	13.90
Men	21	....	$91.00
Totals......Stock	30	....	

Sta. under construction ....

Sta. completed ....

Cu. yd. moved, 378. Cost, 24 ct. cu. yd.

Length of haul ....300 ft.

Kind of dirt...........................Sand and gravel

Remarks ....

....

....

....

Timekeeper.

Fig. 23. Timekeeper's Report Form for Wheeler Excavation.

He handles the levers for controlling the movements of the bucket, in loading, dumping and spreading, and no extra men are required at the scraper in loading or dumping.

In loading, the forward end of the bucket is lowered and inclined forward, so that its cutting edge touches the ground. An end gate at the rear retains the material. When loaded, the front end is raised by the chains on the shaft so as to bring the bucket to a practically level position, when it has plenty of clearance for hauling. An automatic trip releases the clutch when

the scraper is in this position, thus preventing accidental overwinding of the chains and dumping of the load. For dumping, the chains are wound up still farther so as to raise the front end and tilt the bucket backwards, falling clear of the end gate. The load may be dumped in a heap at one spot, or spread in a thin layer, according to the inclination given to the bucket. The operations are shown in Figs 26 and 27, which show the loading and dumping respectively. The front and rear wheels do not

SUMMARY OF DAILY COSTS

Date ....
Job No....................
Foreman ....

Method of Constr.	Area cov.	Cu. yd. moved	Cost per	Total amt.
Fresno excavation	....	....	....	....
Fresno excavation	....	....	....	....
Fresno excavation	....	....	....	....
Wheeler excavation	....	....	....	....
Wheeler excavation	....	....	....	....
Wheeler excavation	....	....	....	....
Grader	....	....	....	....
Grader	....	....	....	....
Grader	....	....	....	....
Trap excavation	....	....	....	....
Trap excavation	....	....	....	....
Trap excavation	....	....	....	....
Rollers	....	....	....	....
Rollers	....	....	....	....
Oil wagons	....	....	....	....
Oil wagons	....	....	....	....
Brushing	....	....	....	....
Totals	....	....	....	....

Average length of haul ....
Average cost per ....
Average cost per ....
Remarks ....
....
....
....
Timekeeper.

Fig. 24. Form for Summary of Daily Cost.

track. This feature (in combination with wide tires and the weight of the machine) reduces the tendency to wear ruts, and is efficient in rolling and compacting the material, as in embankment work.

From two to four horses (or mules) haul the machine, according to the character of the work, but in loading an extra four-horse snap team is generally used. Hard ground must be plowed to enable the horses to do efficient work in loading, but this is not necessary when traction engines are used, as has been

done in several cases. Engines of 12 to 16 hp. have been used for loading, and sometimes they are used also for hauling, the engine taking a train of two to six scrapers.

The cost of loading is estimated to average 4 ct. per cu. yd. in ordinary material. The cost of hauling varies with the grade and condition of road, etc., and ranges from ½ ct. to 1 ct. per cu. yd. for each 100 ft. of haul up to 1,000 ft. Working in a hard and heavy brick clay at St. Louis, a 16-hp. traction engine was

OVERHEAD COSTS

DAILY REPORT

Date ....

Job No....................

Foreman ....

Occupation	No.	Rate	Amt.
Superintendents	1	$5.75	$ 5.75
Timekeepers	1	2.75	2.75
Blacksmiths	1	4.00	4.00
Blacksmiths' helpers	2	2.00	4.00
Stablemen	1	2.40	2.40
Stablemen's helpers	2	2.40	4.80
Water boys	1	1.75	1.75
Camp laborers	2	2.00	4.00
Camp	..	....	......
Camp	..	....	......
Camp stock working	6	1.00	6.00
Camp stock drivers	2	2.00	4.00
Camp stock	..	....	......
Stock idle	1	1.00	1.00
Driving stock	..	....	......
Riding stock	2	1.00	2.00
Sick or idle men	1	2.00	2.00
Sub-foreman brushing	1	3.00	3.00
Men brushing	5	2.00	10.00
Men	20	....	$49.45
Totals......Stock	9	....	

Remarks ....

....

....

....

Timekeeper.

Fig. 25. Form for Summary for Overhead Costs.

used for loading, and three horses to each scraper for hauling. The loading averaged 1¼ min., or 48 loads per hr., with an average of 29 cu. ft. to each load. The machines have been used on railway and reservoir embankments in California; in the latter case the borrow pits were small and scattered, and the haul varied from 200 ft. to 1,500 ft. Their work on the South Branch Canal of the Klamath irrigation project in Oregon (U. S. Reclamation Service) is reported as follows by the contractors, Wells Brothers, of St. Louis.

"From original surface of ground to top of dyke averaged about 14 ft. The canal was built in the embankment and the

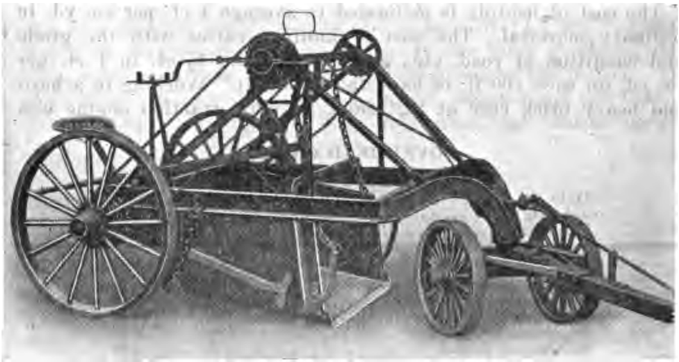

Fig. 26. Maney Four-Wheeled Scraper with Pan in Position for Loading.

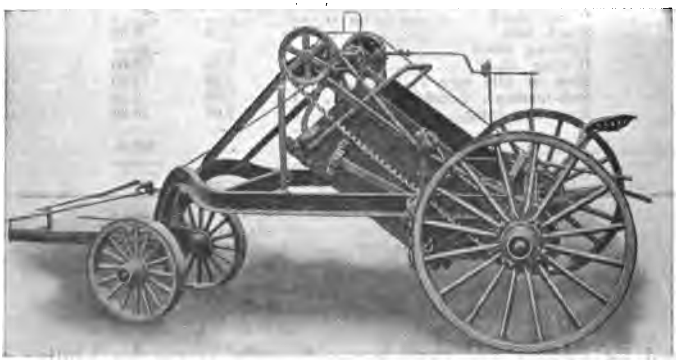

Fig. 27. Maney Four-Wheeled Scraper with Pan Raised for Carrying Load.

bottom of the finished canal was 8 ft. above the original surface of the ground. The entire embankment went up in 6-in. lifts, each lift being sprinkled. The specifications called for each lift being

rolled with a grooved roller weighing 1 ton per ft. of tread, but the Government engineers and inspectors ordered us to take the roller off, as the wheel-scrapers answered to better advantage owing to the front wheels having a narrower tread than the rear ones, and the wheels packing the material better than the roller would have done. The wheels would pack it in low places where the roller would have run over without touching.

"The average haul was 400 ft. from borrow pit to dyke. After 18 in. were removed from the borrow pit, hardpan was encountered requiring eight and ten head to plow. This latter material was handled to the depth of the pit, which was 5 ft. This material could not have been handled at all with grader and wagons, nor with ordinary wheeled-scrapers with profit. The 170,000 cu. yd. handled cost 14 ct. per yd., including the cost of moving to and from the work, which amounted to about $2,000."

These four-wheel scrapers have been used in street and road work, for levees and ditches, railway embankments, canal excavation, and miscellaneous light and heavy grading and filling. On one job 50,000 cu. yd. of loamy soil were removed from ridges and deposited in a pond of water, with an average haul of 200 ft. The cost of this work is said to have been only 10 ct. per cu. yd. In New York, the machines have been used for removing snow, loading it from the winrows formed by plows.

Methods and Cost of Excavating a Canal with Four-Wheel Scrapers. *Engineering and Contracting*, May 31, 1911, gives the following:

At Los Animas, Colorado, an irrigation canal, 50 ft. wide and deep enough to carry about 5 ft. of water, is being excavated with Maney four-wheel scrapers (Figs 26 and 27). The canal follows the contour of a rather broad and level basin and the material is a hard adobe clay. The scrapers were at first loaded with a snatch team and later with a traction engine and cable. The latter method made a reduction in the operating costs of about 1 ct. per cu. yd. The cost of the team outfit was as follows:

4 Maney scrapers at $260	$1,040
12 animals, including 4 on snatch team	3,000
Total	$4,040
Cost of operation with snatch team:	
12 animals, feeding per day	$ 9.00
4 men on machines at $2	8.00
1 pit man	2.50
1 dump man	2.50
1 snap man	2.50
Total	$24.50

With this outfit and an average "lead" of 250 ft., 600 loads of 1 cu. yd. each were made per day of 10-hr., costing about 6 ct. per cu. yd.

The use of the traction engine brought the cost of the outfit up to $5,040, but the output was increased considerably. The traction engine remained stationary in loading the scrapers. A horse was used to drag the cable from the engine to the farthest point for loading the scrapers and the cable was then wound in on the drum of the engine as each scraper load was taken. The cost of operation with the engine in place of the snatch team was as follows:

4 men on machines at $2	$ 8.00
8 animals (feed per team per day), at $1.50	6.00
1 pit man	2.50
1 dump man	2.50
1 snap man	2.50
1 cable man	2.00
1 engineer	3.00
1 clutch man	2.00
Coal	5.00
Haul of water	2.00
Total daily expense	$35.50

With this method about 1,000 loads per 10-hr. day were averaged on a 250 ft. haul, or at a cost of about 5 ct. per cu. yd.

The scraper itself differs from the ordinary scraper not only in the number of wheels but in that the scoop is tilted backward when unloading. The mechanism can be entirely in control of the driver, who operates the levers from his seat in the rear of the machine. By means of these levers he controls the sprocket chains that mesh into the sprocket wheels on the rear axle. The movement of the team therefore dumps the load. The capacity of the scraper is 31 cu. ft.

This "self-loading wagon" is made by The Baker Mfg. Co., 506 Stanford Ave., Springfield, Ill.

Cost with 4-Wheel Scrapers on Road Work. Prof. A. B. McDaniel in *Engineering Record*, July 31, 1915, gives the cost of operating Maney four-wheel scrapers on road construction. In several cases, with soils varying from dry sand to hard, dense clay, it has proved its adaptability and efficiency. In loam and clay soil, with occasional sand and fills of ash and cinders, in Illinois, the cost of operation was 8 ct. per cu. yd with an average haul of 300 ft. on nearly level ground. The width of cut averaged 20 ft., and the depth of cut was from 0 to 18 in., averaging 12 in. Each scraper was hauled by a two-horse team and assisted in loading by a traction engine. The length of working day was 10 hr. The cost was as follows, when each of 7 scrapers averaged 114 cu. yd. per day:

Labor:	
2 firemen, at $3	$ 6.00
1 cableman	2.00
7 teams and drivers, at $5	35.00
Total labor per 10-hr. day	$43.00
1 traction engine and operator	$16.00
General and Overhead Expenses:	
Supervision and general expenses	$ 3.00
Interest on investment (7% of $1,800)	0.62
Depreciation, based on 5-yr. life	0.88
Repairs, estimated	1.00
Total general and overhead expenses	$ 5.50
Total cost of work per day	$64.50
Total amount of excavation, 800 cu. yd.	
Cost per cu. yd. excavated	$ 0.08

Maney Four-Wheel Scraper on Street Work. *Municipal Engneering*, Sept., 1915, describes the use of the Maney four-wheeled scraper as follows:

On a 23,500 sq. yd. vitrified brick pavement job at Pekin, Ill., six Maney four-wheel scrapers were used in the grading of approximately 12,000 cu. yd. These scrapers were loaded by tractor, making a round trip of 1,200 ft. in approximately 14 min., or forty-three round trips per 10-h. day; 43 cu. yd. per scraper, totalling 258 cu. yd. per 10-hr. day. The force engaged in the grading work consisted of seventeen men, six of whom were driving the scrapers, one running the tractor, two trimming up the edges of the cut near the scrapers, three making curb excavations ahead of the scrapers and five men on the dump. The dump is at the edge of the river bank. To reach it from the point at which the scrapers were working it was necessary to haul nearly two blocks over the unimproved street, then to wind around a temporary road, cross several railroad tracks and then skirt the top of the bank to the dump. It was necessary for some of the scrapers to go part way down the bank to dump; others dumped along the top, and the men on the dump trimmed the material up. In returning to the loading point the scrapers took a slightly longer route to avoid interfering with the loaded scrapers moving toward the dump.

Engineering and Contracting, July 3, 1918, reports the use of a 4-wheeled scraper hauled by a small tractor on street and sidewalk grading near Dayton, O. The first use of this method was on a short haul of 80 or 90 ft. Only two men were used on this part of the work — the tractor operator and the scraper operator. The Maney scraper, being self-loading and self-dumping and carrying about 1 cu. yd. of dirt to the load, was easily handled in this manner. On this work no plowing was necessary, as the direct power of the tractor was used for digging, loading and

hauling. A round trip was usually made in about 2 min. or at the rate of about 30 cu. yd. an hr. The cost of operating was stated to be 80 ct. per hr., making the cost per cu. yd. about 2¾ ct.

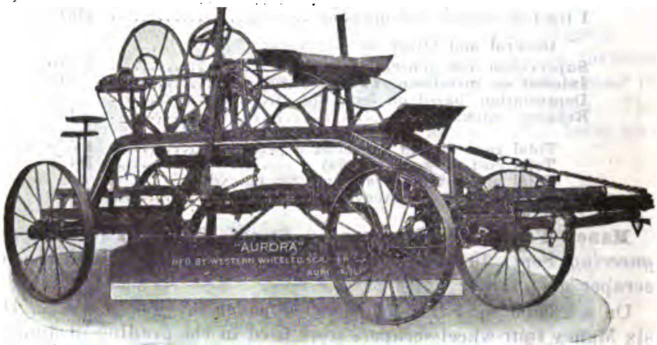

Fig. 28. The Aurora Reversible Road Machine Made by the Austin Western Road Machinery Co.

The tractor and Maney scraper were also used in the same manner for the rough excavating for sidewalks. The cutting was made to within an inch or so of grade and eliminated considerable hand work.

Road Graders. Some makes of road grading machines are pro-

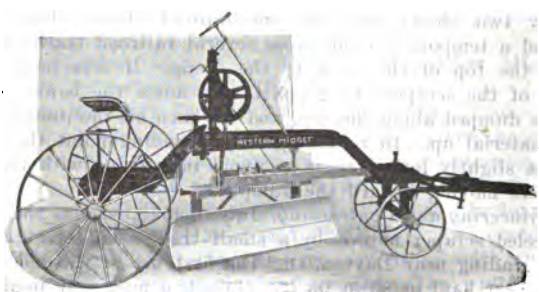

Fig. 29. Western Midget Light Weight 2-Horse Grader. Suitable for Road Maintenance. Made by the Austin Western Mfg. Co.

vided with attachments for shifting the frame back and forth on the rear axle, so as to adjust the blade to a desired position with reference to the wheel tracks, also with devices to lean the wheels at an angle and thus lessen the tendency of the machine

Fig. 30. The 20th Century Farm Ditcher.

to slide over a bank, or to cut the rear wheels at an angle with the frame in order to overcome the tendency to slide when the blade is loaded. Most of the better makes of such machines are now constructed so the blade may be reversed entirely and the convex surface used for smoothing a road after it has been

Fig. 31. Special Fender Attachment for Converting Ditcher into a Bottomless Scraper.

graded approximately to the required cross-section. Machines of this type are made in different sizes and weights and cost from \$175 to \$300 f. o. b. factory in 1914. The heavier sizes are best adapted to construction work and the lighter for maintenance.

A modified form of grading machine consists of a blade similar to that of the machine just described, which is supported by a simple frame on only two wheels. The 2-wheeled machine usually weighs about one-fourth as much as the 4-wheel type and costs considerably less.

A modification of the road grader useful for both grading and ditching is made by the Baker Mfg. Co. of Springfield, Ill. This machine, as illustrated in Fig. 30, is provided with a moldboard 6 ft. long by 13 in. wide with a 5-in. detachable cutting blade. It weighs complete 800 lb. The machine may be used either with or without the front truck. Attachments are made for cutting sage brush and for converting the ditcher into a bottomless scraper. (See Fig. 31.)

Fig. 32. The Martin Ditcher and Grader.

Another type of scraper ditcher, made by the Owensboro Ditcher and Grader Co., Owensboro, Ky., is illustrated in Fig. 32.

Smoothing Machines suitable for leveling and maintaining roads but not for grading are made in various forms. Fig. 33 shows a machine that will level the entire surface of a 30-ft. road. It is designed to be pulled by a tractor of from 15 to 25 hp.

A much simpler machine for the same purpose is the two-blade road drag weighing 290 lb., Fig. 34. Its two 8-ft. blades are each 6 in. wide and are set 3 ft. apart. A similar 3-blade road drag weighs 370 lb. and is 45 in. wide.

Grading Methods and Costs on Earth Road Construction.

Charles H. Moorefield, in *Engineering and Contracting*, Apr. 18, 1917, gives the following:

Where the grade and cross section of the road follow closely the original ground surface, most of the necessary grading usu-

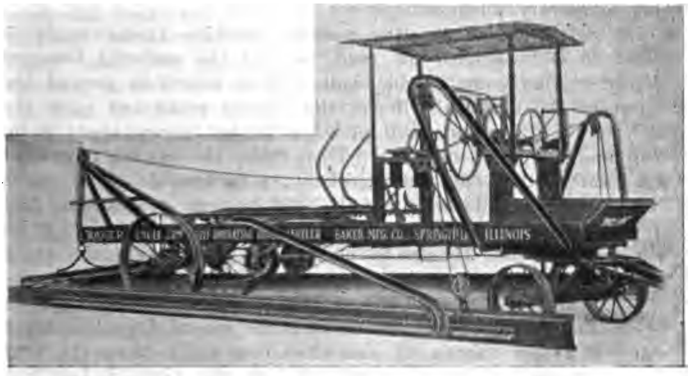

Fig. 33. "Uncle Jim," Self-Operating Road Leveler. Made by the Baker Mfg. Co.

ally may be done with the grading machine. A 4-wheel machine should be used with at least six horses. The team must be accustomed to working together and must be under complete control of the driver.

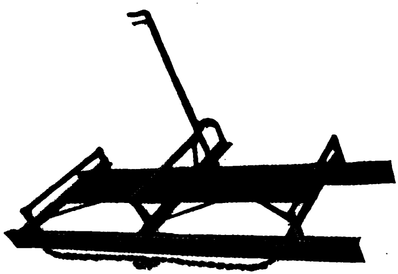

Fig. 34. Prairie 2-Blade Road Drag. Made by Baker Mfg. Co.

Before any machine work is done the area to be graded should be burned or mowed over so as to remove all grass and weeds. The grading should then proceed as follows:

(1) Set a row of stakes 100 or 200 ft. apart along the inside edge of each side ditch. The purpose of these stakes is simply to aid the driver in making the initial furrow of the machine conform with the line of the road, and since the stakes are destroyed by the first furrow they need be only sufficient to serve this temporary purpose.

(2) Set the blade of the grading machine at an angle of about 30 degrees with the road, so that the material loosened by the cutting point of the blade will be moved in toward the center of the road; also lower the cutting point and raise the heel, so that the blade will plow an initial furrow about 6 in. deep and about 18 in. wide. Then make the initial trip with the point of the blade cutting about 18 in. outside of the stake line and the outside rear wheel of the machine against the face of the furrow. The material loosened by the first furrow then will escape under the blade in a ridge just inside the stake line.

(3) Readjust the machine so that when the outside horses follow the initial furrow in making the second trip the blade will cut a new furrow of somewhat less width than the first and the outside rear wheel will follow the face of the new furrow. Then make successive trips with the machine adjusted in this way until the outside edge of the ditch is approached, except that after each two trips it is well to rest the team by readjusting the blade and pushing the loosened material over toward the center of the road. For this latter work the blade may be set at a greater angle with the road, and the heel should be lowered and the point raised, so that the cutting edge will conform closely to the crown of the road while the machine is in operation.

(4) Repeat the above described operation, omitting the stakes and beginning about 18 in. farther from the center each time, until the side ditches are excavated to the required depth and the road is approximately to the required cross section.

(5) Bring the outside faces of the side ditches to a uniform slope by making one or two trips of the machine with two wheels, one front and one rear, on the bank and the cutting edge of the blade against the slope.

(6) Make several trips over the road, cleaning out the ditches and smoothing up the surfaces. The last few trips should be made with the blade reversed, as this method tends to produce a better compacted surface. But, in any event, it is necessary that during the first few months after the grading is completed the road surface should be kept smooth while it is being com-

pacted under traffic. To do this may require frequent use of the grading machine or the drag.

The method of operating a grading machine described above necessarily will have to be modified at times in order to meet special conditions. Where, for example, the ditch area is covered with heavy sod or contains a number of large roots, it may be very desirable to plow this area and cut the roots with an ax before using the grading machine. If this is done the plow furrows should be turned toward the center of the road and the line of the initial furrows should be controlled by two rows of stakes as described above. If the sod is very tenacious it should be harrowed with a disc harrow ahead of the grading machine, and after the material has been moved over toward the center of the road the lumps of sod should be thrown out. A method sometimes followed is to skim off the sod, by means of hand shovels, ahead of the grading machine, but this method is expensive and seldom justified.

Whether or not it is necessary to contend with any considerable quantity of sod, the use of a disk harrow usually will prove helpful in securing a smooth uniform road surface with the grading machine. In general it is sufficient to give the loosened material a thorough harrowing after the road has been brought approximately to its required shape, but before the final shaping is done.

Where continuous long stretches of road are to be graded with grading machines, it frequently is economical to substitute a traction engine for the teams and to employ two machines. Where this is done the first machine is connected immediately behind the tractor, either directly behind or to one side, as the conditions require, and the second machine is connected behind and to one side of the first. Otherwise the method of operation is not essentially different from that already described.

The rate at which a road can be graded up with a grading machine varies to a great extent, and depends largely on the character of the soil. Where the original cross section of the ground is approximately level, and the soil conditions not unfavorable, a grading machine drawn by six well-trained horses should cut out the side ditches and shape the road in from 20 to 35 round trips. Allowing for a reasonable amount of lost time, the rate at which the team travels should average from 1½ to 2 miles per hour, and under the circumstances assumed above, the length of road graded per day should average not less than one-fourth mile. Such favorable conditions seldom are found for any considerable stretch of road, except in the prairie

section of the Middle West, and the average rate of grading with a grading machine is, therefore, much less than one-fourth mile of road per day.

Finishing the Surface. No matter how the grading of an earth road may be accomplished, it usually is economical to bring the road surface to its final shape by means of a grading machine. In making excavations it is not generally considered practical to form the crown and side ditches with scrapers or hand tools alone, and the cross section is, therefore, frequently left approximately flat. The grading machine is then used, in the manner already described, to produce the required cross-section.

Construction Costs. In the following statements and data an effort is made to show the approximate range of cost rather than the average.

The following data (Table I) are intended to furnish a rough guide in making estimates of grading cost at a flat rate per cubic yard. They are based on labor at 15 ct. per hr.; horses at 12½ ct. per hr. The depreciation of grading equipment and repairs are figured at 5% per mo. while in use, and it is expected that the force will be organized economically and managed efficiently.

TABLE I — GRADING MACHINE WORK

Assumed conditions: Original cross section flat; team to consist of six to eight well-trained horses; no material moved longitudinally.

Character of soil	Cost per mile
Light prairie, free from stumps, roots, etc.	$ 60 to $ 80
Average clay loam	100 to 150
Heavy clay, moderate amount of sod and roots, plowing necessary throughout	200 to 250
Heavy clay, exceptionally difficult conditions	From $250 up
Crowning and shaping road which has been graded with scrapers, etc.	50 to 75

Prof. A. B. McDaniel in *Engineering Record,* July 31, 1915, states that in a case of road construction in VanBuren County, Iowa, a 60-hp. gasoline tractor and graders of so-called "reclamation" type were used. Sixty miles of earth road was built at a cost of $20 per mile. The road measured 30 ft. from center to center of the side ditches, which had a width of 20 in. and a depth of 36 in. The earth was the ordinary loam and clay of the prairie country.

The "reclamation" type of grader has pivoted axles, so that the wheels can always be kept in a vertical position; thus the weight of the machines is utilized to counteract the side pressure of the earth on the mold-board, and prevents side draft. Where a large amount of road construction is included in one job, it is economical to use a traction engine for hauling the grader.

Two graders may be hauled by one engine, and thus serve to move the earth from the ditch to the center of the road at one trip.

Tractor Grading. *Engineering and Contracting*, Oct. 4, 1916, gives the following: Tractor-grader outfits are being used extensively in Utah on highway work. One of the most notable undertakings with these outfits was the construction of approximately 100 miles of earth road in Box Elder County. This work was carried out in 1914 by the State Road Commission. The highway was constructed over a virgin soil, sage brush country, on a new location encircling the north end of Great Salt Lake. It extends southwestwardly from Snowville to intersect the Nevada line just west of Lucin and forms part of the Midland Trail.

Two International Harvester Co.'s Mogul gasoline, 60-hp. traction engines and two road graders handled the work almost exclusively. A cross section 24 ft. wide from gutter to gutter

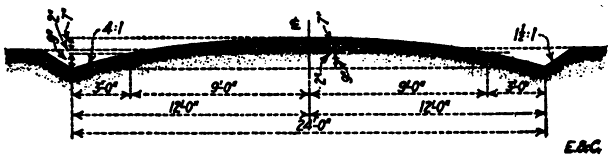

Fig. 35. Cross Section of Midland Trail, Box Elder County, Utah.

with 9-in. crown above the shoulders was adhered to almost entirely, the width of the road being increased, however, to 30 ft. in width, through towns and settlements. The cross section mentioned is shown in detail in Fig. 35.

The progress of the grader and traction work on the longer tangents of the road amounted to an average of 1¼ miles per 10-hr. day, the cost being $75 per day, or a unit cost of $60 per mile. The record run made on this project for grader and tractor work was 2½ miles per day at the same rate, amounting to only $30 per mile of road, thereby surpassing all previous records for speed and economy of road construction in the state. Surveying, clearing right of way, plowing and finishing, however, amounted to considerable; moreover, many stretches required team and hand construction. The average cost of the 100 miles of road was $275 per mile, not including bridges and culverts.

Two Road Graders Used with a Tractor. The following is from *Engineering and Contracting*, May 15, 1918. Using power machinery only, 125,000 cu. yd. of dirt were moved last summer on an Illinois road job, at a cost of 4.1 ct. per cu. yd. The

work was done in connection with the improvement of a road leading north toward Pontiac, Ill. The first 5 miles of this highway was changed from a narrow winding road to a level, well drained all the year road, 60 ft. wide between fences and 40 ft. wide between drainage ditches.

The work of clearing the right-of-way was started on May 1, 1917, and completed June 16, 1917, during which period 5.18 acres were cleared of a tangled mass of brush and shrubs and over 200 live trees from 3 in. to 3 ft. in diameter. Trees were pulled by a 75-hp. caterpillar tractor using a 100-ft. cable. Two cable outfits were used, so that the tractor was not delayed

Fig. 36. Leveling Crown with Graders.

waiting for hitches to be made. The cost of clearing the roadway, including labor, interest on investment and an allowance of 20% for depreciation of equipment, was $990, or $191 per acre.

The grading was started on June 18, 1917. One 75-hp. caterpillar tractor was used to pull two Western graders, one 12-ft. to make the cut, followed by an 8-ft. to carry the dirt to the center of the road. A Western elevating grader pulled by a 75-hp. caterpillar tractor was used in some places in making fills. However, on some of the deeper fills it was necessary to use some other method, in order to make time, and a 75-hp. caterpillar tractor was used in connection with a caterpillar land leveler. This land leveler is a tool used extensively in the West and is in reality a large scraper having a capacity of approximately 3½ yd., see Chapter VI. With this machine the dirt could be

taken up and carried across the road and then unloaded gradually or at one time, as conditions required.

The gravel for the surfacing of the road was taken from a near-by creek with a dragline excavator which delivered it to a loading hopper. With the dragline excavator working steadily it was possible to keep the hopper filled, so that when the tractor trains came up, which consisted of one 75-hp. caterpillar tractor and six reversible trailers, they could be loaded without delay or without shoveling.

With this equipment a total of a little over 125,000 cu. yd. of dirt was moved in 75 working days. The total cost, including labor, interest on investment and an allowance of 20% covering

Fig. 37. Caterpillar Land Leveler on Road Work.

depreciation on equipment, was $5,147, or 4.1 ct. per cu. yd. At no time were more than 8 men, including the superintendent, employed on the job. Horses or mules were not used at any time in the work.

A Large Drifting Scraper and Tractor is described in *Engineering and Contracting*, Feb. 19, 1919. In developing the 70,000-acre tract of the Crocker-Huffman Land & Water Co. at Merced, Cal., several interesting dirt-moving methods were employed by Mr. Henry Lage, manager of the company. In building the irrigation ditches the dirt was loosened by a scarifier hauled by a caterpillar tractor. Scrapers and mule teams were employed in scooping out the dirt loosened by the tractor and scarifier. Previous to the use of the outfit, the dirt had been loosened by means

of road plows pulled by mule teams. Five 16-mule teams were used in this work and each plow required three men to hold it, in addition to the driver. For the five outfits, 20 men were required, which at $2.25 made the labor cost $45 per day. The total cost, figuring the 80 mules at $1 each per day, amounted to $125. With the tractor and scarifier outfit the cost of loosening the dirt was $18 per day—the cost for the tractor and the operator.

One of the greatest problems in connection with the development was the leveling of the land. Livestock was first used for the purpose, 400 mules being employed with fresnos. Later caterpillar tractors were substituted for the mules, one tractor being used with seven fresnoes. The difficulty with this method was that one man was required with each scraper, and with seven men in each battery of scrapers, it was difficult to get the unity of action necessary to make the work completely successful. Mr. Lage then proceeded to experiment and finally brought out a land leveling machine which he termed a ground plane. With this plane he was able to do as much work as he had heretofore accomplished with 24 mule teams and fresnoes. The plane has since been developed and improved by the Holt Mfg. Co. and is now known as the Caterpillar Land Leveler.

The machine is designed and built especially for use with tractor power. In the largest size (11½ ft. leveler) the bowl is 2 ft. 5 in. high and the wings extend 3½ ft. forward. The capacity is 4 to 5 yd. The smallest size (6 ft. leveler) has a capacity of 2 to 2½ yd. The bowl is raised or lowered while the leveler is in motion by a power device, consisting of a sprocket keyed to the axle and another one running loose on the upper shaft but attached to a friction cone clutch by means of which the connection between the drive and shaft is made. When the machine is standing still the bowl can be raised by a large hand wheel. The depth of cut thus can be regulated, and the load dumped in one place or spread evenly.

Road Grading and Dragging with Tractor. The following account appears in *Engineering and Contracting*, April 2, 1919.

By using a light tractor for hauling in grading the Road Commissioners of Marquette county, Michigan, were able to carry out work equivalent to that accomplished by a 3-team grader outfit. The tractor-grader outfit was used for trimming of shoulders and reshaping grades when the work was light. In the grader work, it was found that the machine made cuts, which were nearly equivalent to two team cuts but not quite as heavy, that it operated nearly twice as fast as teams successfully, but that any higher speed was too fast to do the work well. It was

therefore considered that the tractor, taking into consideration its power plus its effective speed, replaced from two to three teams in such work. It is planned to use the tractor continuously on a section gang, combining two of the sections, where team hire is difficult, and putting on a section gang instead of having a patrolman and a drag man for each section.

A light tractor also was employed during the 1918 season in dragging operations. In this work the drag man found that he could make his section in approximately 5 or 6 hours, entirely covering it, during the period when his section was all in the proper condition of moisture for drag maintenance. The section in question, is a stretch on the outside end of one of the county roads and is entirely wooded. Dragging with horses, it took a full day of 10 hr. and often an hr. or two overtime to cover the section. K. I. Sawyer is County Road Superintendent.

Earth Moving Methods and Equipment for Road Construction are described by A. R. McVicar, in *Engineering and Contracting*, April 2, 1919.

Cost of Grading with Drag or Slush-Scrapers in order to do good work with the scraper it is necessary to have the ground properly plowed and, therefore, we must select the proper plow. As for the long handled farm plow, on account of the shape of the mould board, in stiff clay or gumbo, this plow simply turns the furrow over, leaving it almost, if not entirely, intact, making it almost impossible to load into a scraper. The railroad plow, on account of the abrupt out-turn of the mould board, leaves the furrow broken into short chunks, a proper condition for loading.

All classes of earth, no matter how loose or soft, require to be plowed, for the reason that you will find a certain suction in unplowed earth that does not exist in plowed earth. It is necessary to plow narrow at all times, and for shovels or slush-scrapers, as deeply as possible. It is not necessary nor advisable to plow so deep for wheelers. I would like to make this claim for the slush-scraper, that there can be more earth moved in the same time for less money with the slush-scraper than with any other device known. That is to use it where and how it is intended to be used, viz., making a side fill, a side cut and fill, or wasting a cut to a depth of not more than 6 ft.

It takes five scraper holders and one 4-horse plow team and ten "slusher" teams to make a complete gang, the ten scrapers to be divided into five swings, with one holder and two teams to each swing, with one swing to every 100 ft. of road. By keeping the teams going in a circle they will move 1,080 yd. per day, or an average of 90 yd. per team, plow teams included.

At a rate of $6 per team, the cost per team and half the time of a scraper holder would be $7 per day; that would be moving this earth for 7⅔ ct. per yard. Taking an end haul of 100-ft. distance, including the turn at either end would bring the round trip up to 250 ft. Traveling at the rate of 2½ miles an hour, eight scraper loads per cu. yd., would be moving 30 yd. per team, costing 21⅓ ct. per yd. Two No. 3 wheelers, one snatch team, one 4-horse plow team, two wheeler-holders and one dump man on this same haul at a total cost of $36 per day will move 300 yd. or an average per team of 60 yd., bringing the cost, per cu. yd., moved at 12 ct. Increasing this haul to 200 ft. with the slushers would bring the cost per yd. to about 21 ct., an extra cost of 9⅔ ct., while the cost with the wheelers would increase to 14½ ct. per yd. or an extra cost of about 2½ ct.

By these figures you will see that the economic limit of the slusher haul is where you leave the circle. The limit of the wheeler haul is about 600 ft. But in the event of replacing the wheelers with dump cars the limit should be considered 400 ft., being the distance where the cost of wheelers equals or exceeds that of the cars.

Grading with Grader or Road Scraper. I have tried out the road grader drawn by two teams of horses that proved very satisfactory. Then I tried three teams. This was more of a success, but altogether too expensive. I then secured two 8-16 hp. kerosene tractors, which proved to be a little on the light side. I then got a 10-20, which seems to be alright. I have been told that the 10-20 is also too light, but that is a matter of opinion, as I believe that the tractor is heavy enough for the grader and that the grader is heavy enough for the work I have to do.

The earth can be taken off the roadbed or onto it in better shape by going twice over it with this light outfit than by pulling up a conglomerate mass of lumps and stones with one turn of the heavier outfit.

We have in connection with this outfit a van in which the operators live. We usually leave this van about 1 mile from the end of the road and work both ways from it.

In starting work where the ditches are formed, that is, after a fashion, we have the sods removed from the outer edge of the ditch towards the fence, that is, where the roadbed is not the required width. Next, I have the sod shoulders on the roadbed removed toward and then across the ditch on to the boulevard. This being done, if we find that the ditches are deep enough for proper drainage and the center of the roadbed high enough, we then continue to heel off more from the shoulders. This earth follows the sod to the boulevard. By doing this we are

forming the crown of the road as well as lessening the apparent depth of the ditch, although in reality deepening it. Next the grader passes up and down the center of the road with plenty of pressure on the blade to remove all the solid lumps. This is to have as smooth a surface as possible to receive the loose earth which is to come up from the ditch in the finishing process. Having this smooth surface to receive the loose earth is as necessary as to have a smooth and uniform surface on which to lay a permanent pavement. This road, when finished, has a width of 24 ft. and a crown of 12 in.

A Gasoline Tractor on Road Work. Mr. G. R. Buchanan in *Engineering News*, Aug. 27, 1914, presents some very interesting data regarding the use of gasoline traction engines on road work in Caroline County, Va. The type of tractor selected was a combination kerosene-gasoline tractor, costing $3,000. This tractor developed 50-hp. on belt pull and 25-hp. on draw-bar pull. More tractive power was developed on gasoline than on kerosene, and while the former fuel was more expensive it developed that 1 bbl. of gasoline lasted as long as 1.25 bbl. of kerosene. The fuel tank was of 1-bbl. capacity, and this lasted from 7 to 10 hr. when the machine was running.

Grubbing was attempted with the tractor but, after a few successful efforts, the gears were badly smashed. In one case, damage to gears amounting to $150 were made on a tree stump which could have been blown up with dynamite costing less than $1. Probably if the belt power of the tractor had been applied to a stump puller it might have proved successful.

The tractor regularly hauled when grading two large size Buckeye road graders of a much heavier type than are commonly used in the South. These machines when hauled by mules required six animals. In hauling with the tractor the graders were set very much deeper than it was possible when hauling with mules. One grader was hitched with an angle-coupling so that it ran in the ditch, with the steering gear locked to hold it in that way. This obviated the necessity of the steersman required with mule graders. The second grader was hitched to a double-length pole, so that it followed the first grader and caught the dirt thrown from the ditch, and pushed it further toward the ground. Work was done with tractor-drawn grader in two trips which required no less than ten trips of the mule drawn grader.

There is some work that tractors can not possibly do, such as light hauling, patching ruts, and filling from borrow pits. It was estimated that the tractor moved earth for 2.8 ct. per cu. yd., which by mule power had cost 3.2 per cu. yd. These figures

covered labor, fuel, lubricating oil, etc., for the tractor, and feed, stable cost, labor, etc., for the mules, but not depreciation charges.

The depreciation of the tractor during the season was figured at $800, while a maintenance account of repairs of about $400 was incurred. This repair charge was largely due to breakage in gears resulting from stump pulling. During the season the tractor moved about 100,000 cu. yd. of earth, which gives a depreciation and repair cost of $0.0012 per cu. yd.

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CHAPTER X

METHODS AND COST WITH CARS

General Types of Contractors' Cars. Cars used for hauling earth may be divided into four general classes: Non-dumping cars, " static " and " rotating " dumping cars and tipple dumping or mine cars.

Non-Dumping Cars consist almost entirely of the standard broad gage railroad flat cars. They are loaded in various ways, one of which is by a special type of steam shovel known as a railway ditcher which is mounted on a track on top of the cars and which works its way along the train filling the cars behind it. These cars are emptied by drawing a heavy plow unloader

Fig. 1. Loading Non-Dumping Flat Cars.

attached to the locomotive by cable from one end of the train to the other.

Static Dumping Cars are so arranged as to hold the burden in a quiescent state, and are unloaded by the opening of a gate in the bottom or side, allowing the load to flow gradually out. Their greatest effectiveness is obtained in discharging an easily-flowing burden containing a certain amount of " life "— that is, a material that does not adhere to itself or the car, such as sand, rock, gravel, etc.

Rotary Dumping Cars are mounted trucks which remain stationary while the body is overturned or tilted at an angle suffi-

cient to discharge the load either to one side or the other. While the body is in process of being tilted, the sides or gates for retaining the burden are automatically lifted or lowered or swung outward, so as not to interfere with the sliding movement of the load in process of dumping. There are two classes of car

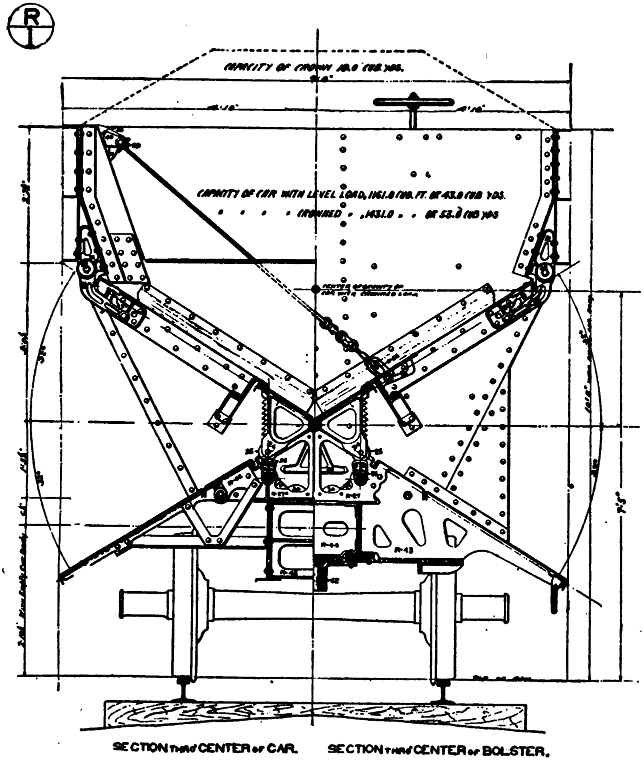

Fig. 2. The Goodwin Patent Dump Car.

included in this type, those requiring individual dumping and those dumping by air or other means making it possible to discharge a whole train load at once. Rotary cars are particularly adapted to the carrying of clay, earthy soil, alluvial material, etc. They are generally used for hauling earth.

Fig. 3. 30-Ton Side Dump Car.

Fig. 4. 3-cu. yd. Side Dump Car (Made by Kilbourne and Jacobs Mfg. Co., Columbus, Ohio). Wheel Base 48 in., gage 36 in., Weight 4,300 lb.

Rocker Double Side Dump Cars are widely used on construction work. Fig. 5 shows a car of this type made by the Easton Car Construction Co., of Easton, Pa. These cars are made for capacities of from 18 cu. ft. to 135 cu. ft. and weigh from 900 lb. to 6,900 lb.

Tipple Dump or Mine Cars can only be used in connection with an automatic dumping device. In general the car is tilted truck and all and at the same time an end gate is held open until the material slides out.

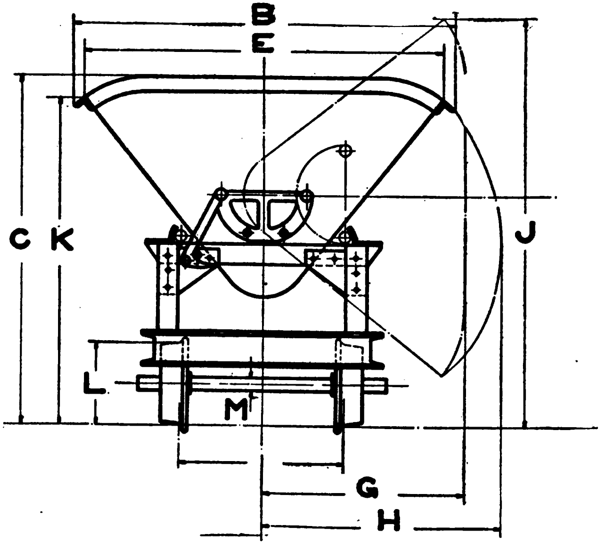

Fig. 5. Rocker Double Side Dump Car.

Track Mover. Samuel A. Taylor, in an address before the Railway Club of Pittsburgh, in 1911, gave a description of a track moving machine which is used on earth dumps. The operation is described as follows: When the fill has been made to such a width that they wish to move the track over, the track mover, consisting of heavy chains and hooks hanging from the end of a boom, takes hold of the track and lifts it until the ties are clear of the ground. Then a side arm, in which is placed a pulley on which a wire rope passes, having hooks attached to the end, is then fastened to the rails. This rope is operated by a small engine, which swings it over to its new position. That

machine displaces a great deal of labor and is very economical in cost of operation.

A Track Throwing Car. An interesting device, invented by Davis Creerse, was described and illustrated in *Engineering News*, Dec. 21. 1899. This apparatus (Fig. 7) is fitted to the rear end of a flat car. It consists of a timber frame on which is a hand hoist operating a bull pole. The end of this pole carries a 14-in. wheel which, when the machine is in operation, bears against the web of the outer rail. When in operation the car

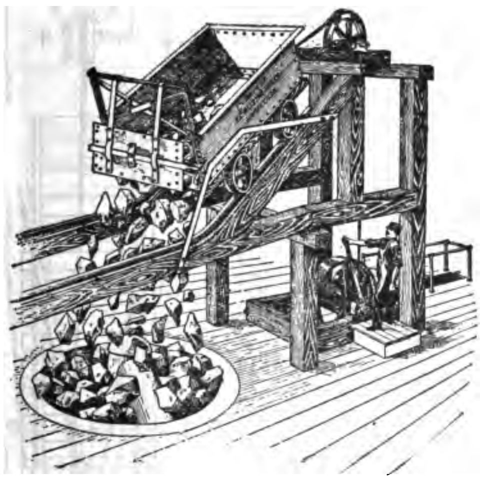

Fig. 6. Tipple Dump Car Made by Austin Mfg. Co., of Harvey, Ill.

is heavily loaded with iron rails and is hauled over the track, the "bull pole" throwing the track at the rear of the moving car. The track may be shifted any distance from 6 in. to 3 ft.

Switch for Narrow Gage Tracks. Fig. 8, which is taken from *Engineering and Contracting*, Sept. 28, 1910, shows a contractor's switch which is very simple of construction and operation. It is also quite rigid and strong enough to carry heavy loads without a great amount of wear. The idea, as shown, is in joining the two inside rails together as a switch point and shifting the point back and forth between the outside rails in the positions indicated on the plan. The ties are capped with ½-in. plates as wearing surfaces and the switch points are braced rigidly. The design is the idea of Mr. C. R. Neher, who is constructing en-

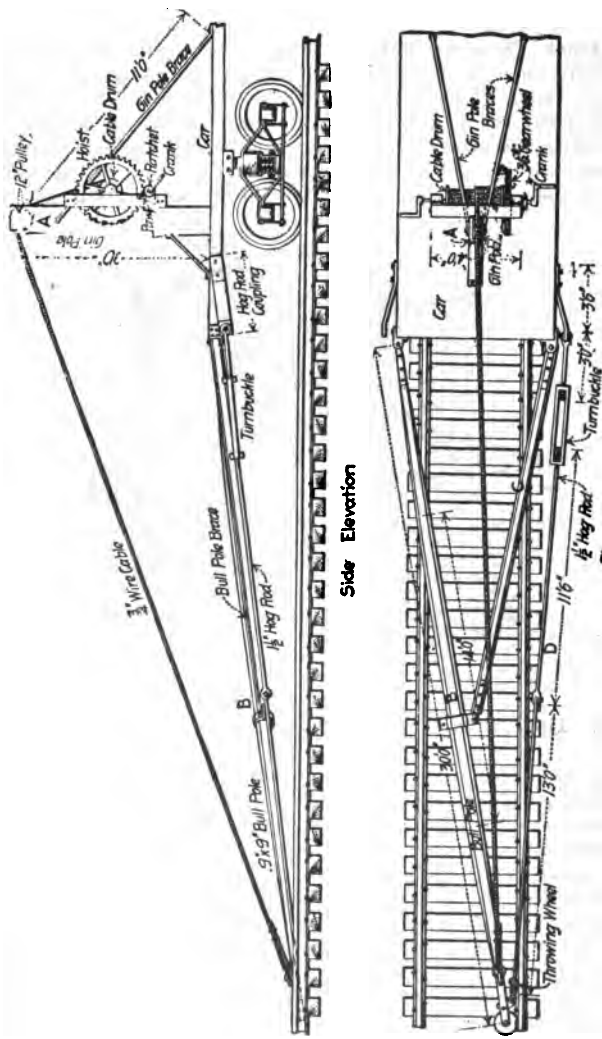

Fig. 7. Details of Track-Throwing Car.

gineer for the Atlantic, Gulf & Pacific Co., at Whitehall, N. Y., and the switch has been used in the contract work of this company in a number of places.

Use of Cars. In ordinary construction work light (3-yd.) cars are generally run on light rails (16 to 40 lb. to the yard) with ties wide spaced (4 ft. c. to c. usually) and not ballasted. To lay such track with labor at 30 ct. per hr. has cost the author about $4 per 100 ft. of track, or $200 per mile, after delivery of materials. The author has used 4 x 4-in. ties, but cannot recommend them, for after once using they are so split by the spikes

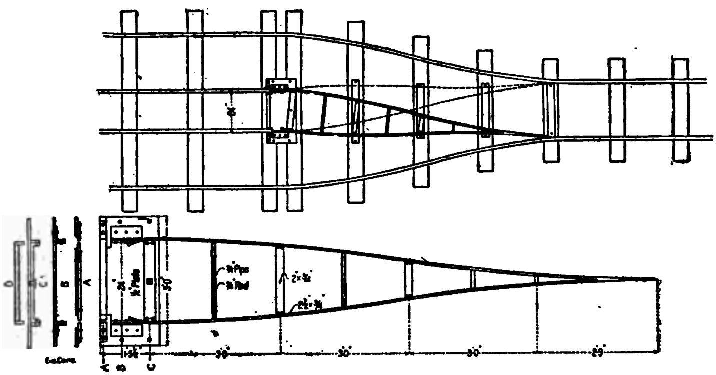

Fig. 8. Details of Special Contractor's Switch.

as to be of little value. A 6 x 6-in. tie, 5 ft. long, is the best for general use on these narrow-gage roads.

Roughly laid as such track is, with light rails, and wide spacing of ties, it is not safe to estimate the rolling resistance at less than about 40 lb. per ton of load on the car wheels (including the weight of car itself) on a level track.

It is very commonly stated that 20 lb. is the force required to pull a 2,000-lb. load over light rails. This may be so over carefully laid, clean track, with ties close-spaced, and with car wheels well lubricated; but over the ordinary rough contractor's track, 20 lb. is much too low an estimate.

In the "Coal and Metal Miners' Pocket Book" is a table giving actual results of traction tests, including several hundred separate tests under varying conditions. From these tables we have summarized the following:

	Per short ton
Pull to start mine cars (old style) loaded	90 lb.
Pull to start mine cars (new style), empty	80 lb.
Pull to keep up ¼-mile per hr. speed (old style car)	50 lb.
Pull to keep up ¼-mile per hr. speed (new style car)	33 lb.
Pull to keep up 4½-mile per hr. speed (old style empty)	56 lb.
Pull to keep up 4½-mile per hr. speed (old style full)	66 lb.
Pull to keep up 4½-mile per hr. speed (new style empty)	80 lb.
Pull to keep up 4½-mile per hr. speed (new style full)	38 lb.

The foregoing was for trains of 1 to 4 cars, but with a train of 20 cars the pull was 46 lb. for old-style cars and 26 lb. for new-style cars per short ton on a level track. The mine cars used had a wheel base of 3.5 ft; they weighed 2,140 to 2,415 lb. empty and 7,885 to 9,000 lb. loaded. The diameter of the wheels was 16 in., and of axles 2⅛ in. for old-style car to 2½ in. for new-style car, with a steel journal 5¼ in. long, well lubricated in all cases, in fixed cast-iron boxes. The new-style cars had better lubrication, the importance of which is well shown by the results of the tests. The track in the mine was level and in good condition.

The resistance to traction on upgrades is practically 20 lb. per short ton for each 1% (1 ft. rise in a 100 ft.) of upgrade; so that on a 5% grade, for example, it will require a 100-lb. pull on a rope to overcome the gravity resistance of a ton, plus 40 lb. more to overcome the rolling resistance, or a total of 140 lb. per ton. Working steadily for 10 hr., a single horse can just about do the work necessary to pull a car up a 4% grade, that is the tractive force of a 1,200-lb. horse is about 120 lb. working steadily all day long; in other words, a horse can exert a pull on a rope of about $1/10$ its own weight. Many a contractor will say that this is absurdly low, but experience has shown it to be not far from right. However, for a short time a horse, like a man, can exert a great deal more force.

The author has had a heavy team pull a load of 10,000 lb. up a 5% grade on a macadam road; and actual test on a spring balance has shown that a light pair of mules have exerted a pull of 1,000 lb. (or 500 lb. each) ascending a steep earth road.

So it is evident that for a few minutes a horse can exert a pull about 500 lb. if he has a good foothold, but he must have long rests between such exertions. It requires about two times as much force to start a car as it does to keep it in motion, hence a horse should never be worked within half his capacity, that is he should not be required to exert over 250 lb. pull at any place where cars are apt to stop.

A dump car with a box 2 ft. deep, 5 x 5.5 ft., holds 2 cu. yd. water measure, but even when heaped up with loose earth it will seldom hold 2 cu. yd. of earth measured in cut. Such a dump

car weighs about 2,000 lb. and 2 cu. yd. of earth (place measure) weigh about 5,400 lb., or a total of 7,400 lb., or 3.7 tons. A strong horse could pull one such car loaded on a level track all day long, and could go up a short 4% grade occasionally if he did not stop on the grade. Cars will coast down a 2% grade once they are started, so it is not advisable to have steeper grades, when brakes are not provided for the dump cars.

Mr. P. B. Lieberman in a paper in *Trans. Am. Inst. M. E.*, Vol. LV, 1917, gives the result of tests made at the Greensburg Coal Co.'s mine at Greensburg, Pa., on mine cars with and without roller bearings. His conclusions were that the use of roller bearings reduced the draw bar pull 47% on speeds of between 5 and 6 miles per hr.

On the Chicago Drainage Canal a great deal of material was loaded with a steam shovel into small dump cars that were hauled away by horses on a slightly down grade to the foot of an "incline," where they were pulled with a ¾-in. wire cable to the top of the bank by a 60-hp. winding engine (13 x 16-in. cylinder) stationed at the top of the bank; the cars were then hauled to the dump by horses. One team pulled two cars holding 3 cu. yd. each, or five cars holding 1 cu. yd. each. The same team could pull back 6 empty 3-cu. yd. cars. Two faces were worked in opposite directions from each "incline." Even then the "incline" engine could handle more material than two shovels could excavate. In one case 2,400 cu. yd. were raised in 10 hr. An extra team was used to "spot" the cars. (See Gillette's "Rock Excavation.")

In excavating mud the author once used an incline 120 ft. long rising 12 ft. in that distance; then there were 80 ft. of level track at the foot of the incline and 40 ft. of level track on a trestle at the top. Using a team of horses and a single car holding 1 cu. yd., with a hemp rope passing around a pulley at the top of the incline, 120 carloads were raised every 10 hr. The team actually traveled 14.5 miles a day in doing this work, part of which it will be seen was exceedingly hard.

There are many comparatively small jobs where a few dump cars and some light rails will enable a contractor to move earth far cheaper than with wagons. Ordinarily the dumping of the cars where the fill is light will cause the earth to run back and block the track. It is therefore customary first to build a temporary trestle, and fill it in with earth; then the track is shifted from time to time to keep it close to the edge of the embankment. Even where the fill is so light as not to pay to trestle, the author has found cars economic; for then the earth can be shoveled from the cars at a cost of 12 ct. per cu. yd. (wages

being 30 ct. per hr.), which is often less than the added cost of hauling with wagons.

Cars Moved by Hand. In excavating narrow open cuts, or tunnels either in earth or rock, a small dump car running on 16-lb. rails is often used with profit. A man can readily push a small dump car holding ⅓ cu. yd. of earth (nearly half a ton) on a well laid, clean level track at a walk of 220 ft. a minute all day long. With wages at 30 ct. per hour the cost of moving earth in this way is 1.5 ct. per cu. yd. for every 100 ft. of haul, which it will be seen is very much less than the cost, 10 ct. per cu. yd., by wheelbarrows for every 100 ft. of haul. In view of this low cost, and in view of the ease with which a 16-lb. track can be laid and shifted when made in one rail sections, it is surprising the contractors do not oftener use the small end dump car pushed by a man.

Cars and Portable Track. G. P. Blackiston in *Engineering and Contracting,* July 13, 1910, gives the following:

An immense bank of special earth was practically encircled by a deep canyon with the exception of a very narrow stretch of land connecting the mainland as it were, with the high bank.

The margin of profit being small, ordinary methods of transportation were out of the question. The length and narrowness of the stretch of connecting land did not permit the use of wagons or carts, while the use of steam shovels at the working end was quite out of the question due to the impracticability of transporting the shovel to the bank. The use of dump cars operated upon portable tracks was also impracticable unless they could be loaded with the minimum of labor. This, therefore, meant that the material could not be transported at any distance in shovels from the bank to the cars; in short, that the cars must be placed at the very feet of the laborers shoveling — permitting them to transfer the earth directly from the bed to the car — yet there was no room for a vast complicated system of switches.

With all this to contend with, the contractor laid a portable railroad across the narrow strip of ground to the bank. Here, by means of several short spurs, Fig. 9, he placed his cars abreast at the distance of about 10 ft. apart. This permitted the laborers to load the respective cars from three sides and without moving a step to secure the load. As the work progressed another section of the portable track (attached to steel ties) was laid and the next cars loaded at a position closer to the base of supply. The cars when loaded were conveyed by gravity to the unloader on the opposite side of the ravine, some 626 ft. away.

By this method coupled with the use of steel dump cars and portable tracks made by the Orenstein-Arthur Koppel Co., Pittsburgh, Pa., the material was loaded, conveyed and dumped for less than 6.3 ct. per cu. yd.

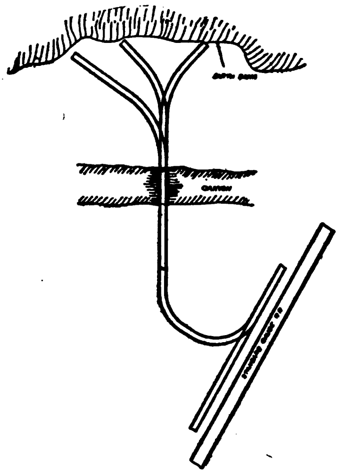

Fig. 9. Track Arrangement for Loading Cars by Hand.

Cost with Horse-Drawn Cars. Hauling cars with horses is ordinarily cheaper than with locomotives for short distances, unless the contractor already has the locomotives on hand.

Referring to the forepart of this chapter, it is seen that a strong team will pull about 5 cu. yd of earth over fairly level track at a walk. With a speed of team 2.5 miles an hour, the cost is $1/330$ of an hour's wages of team and driver per cu. yd. for every 100 ft. of haul from pit to dump. At this rate it is as cheap to haul with horses as with locomotive up to a distance of nearly a mile, provided, of course, that a contractor has to rent or buy the locomotive, and does not already have it on hand. A locomotive, however, possesses one decided advantage in that it can push cars out into a trestle; whereas, a block and tackle must be used with a team to get the cars out onto the trestle. If there were no delays either at the pit or at the dump, and a team were moving all the time, we thus see that it could haul 3,300 cu. yd. 100 ft., or 100 cu. yd., 3,300 ft. Manifestly the first rate is impossible not only because there are necessary delays, but because enough men could not be got

around the cars to load 3,300 cu. yd. a day. Ordinarily where cars and a team of horses are used about 20 shovelers are employed, seldom more than 30 shovelers, not infrequently only 10. Ten men working at a face of earth may each undermine and load 15 cu. yd. a day, which a team could haul in cars a distance of 2,200 ft., making 30 round trips if there were no delays. As a matter of fact there will be about two minutes consumed each trip changing team from the empty to the full cars, and another four minutes at the pit dumping. Delays while shifting track will ordinarily add about four minutes more each trip, making a total of 10 minutes "lost time" each trip, or two minutes for each cu. yd. This means a cost of $\frac{1}{30}$-hr.'s wages of team and driver for lost time per cu. yd. hauled. In this 10 minutes "lost time" the team could travel 1,100 ft. and return; hence, instead of travelling 2,200 ft. and return as above assumed, the team would really have time to travel only half that far.

Rule. To find the cost per cu. yd. of loading from a "face" and moving average earth with cars and horses, add together these items:

$\frac{2}{3}$-hour's wages of laborer undermining and shoveling earth.

$\frac{1}{30}$-hour's wages of team with driver "lost time."

$\frac{1}{8}$-hour's wages of man on dump, dumping, making trestle, and track shifting.

Then add $\frac{1}{330}$-hour's wages of team with driver for each 100 ft. of haul. With wages of man at 30 ct., and horse at 15 ct. per hr., this rule becomes: To a fixed cost of 32 ct. add 0.2 ct. per cu. yd. for every 100 ft. of haul; and add the cost of materials for the dumping trestle plus $250 per mile of track, divided by the total number of cu. yd. moved over the track before it is torn up.

NOTE.— Where a steam shovel is used, hauling cars by horses is especially disadvantageous because of delays in switching and "spotting" cars in such short trains as team hauls.

Cost with Horse-Drawn Cars. The cost of excavating and transporting earth with Koppel 1.5-yd. V-shaped dump cars at Attleboro, Mass., is given in *Engineering and Contracting*, Sept. 30, 1908.

These cars were operated on a 30-in. gage track, and were 4 ft. 5 in. high, and about 5 ft. 7 in. wide They weigh 1,080 lb. Some of them were equipped with brakes. The cars were operated in trains of 4 cars, and coasted to the dump by gravity, being hauled back to the cut by one horse and a driver. Thus five horses were used for the 40 cars. The dead load pulled back by the horse was about 4,400 lb. A 20-lb. rail was used, laid on

wooden ties, spaced at 3-ft. centers. In all 2.25 miles of track was used on the job. Several turn outs and switches were used, thus allowing the cars to be kept almost continually in motion.

The total cost for plant outside of small tools was:

40 cars at $90	$3,600
70 tons rails at $32	2,240
4,000 ties at 12½ ct.	500
Total	$6,340

Estimating interest, depreciation and repairs to the outfit at 2% per month, we have a monthly charge of about $127 for plant. The material was a boulder clay, consisting of loam, clay, gravel and hardpan, and while most of it required but little loosening with picks, yet some of it had to be drilled with short holes and shot with 20% dynamite. Some of the work, where the banks were low, was worked from on top, but most of it was worked from abreast. Men shoveled the material with short handled shovels.

The excavated material was hauled from 700 to 1,000 ft., the average haul being about 850 ft. There were 80 men employed on the job working under 3 foremen.. A 10-hr. day was worked.

During the month of June in 25 working days, 15,000 cu. yd. of material were excavated. The cost for this work was as follows:

3 foremen, 25 days at $5	$ 375.00
75 men, 25 days at $1.80	3,375.00
5 drivers, 25 days at $1.80	225.00
5 horses, 25 days at $1	125.00
300 lb. dynamite at 10 ct.	30.00
Plant charges (estimated)	127.00
Total for 15,000 cu. yd.	$4,257.00

This includes all the cost except general expenses, and the month's proportion for laying track. The item of transportation for an 850-ft. haul is low, since it amounts to only ¼ ct. per cu. yd. per 100 ft. of haul. The total cost was 28.3 ct. per cu. yd.

Comparative Costs with Wheelers and Cars. The following data of the cost of grading 25,000 cu. yd. of average earth for a railroad siding near Homewood, Pa., is given by Mr. Arthur Reiche in *The Industrial Magazine*, Aug., 1907. Part of the work was done by scrapers and part by Koppel 1-yd. double-side dump, V-shaped cars.

The car work was in a wide cut and borrow pit, the bank averaging 5 ft. in height. Two-thirds of the material was average earth, the remainder being hard gravel requiring a three-horse rooter plow for loosening.

Portable track of 24-in. gage with steel ties, was used. The cars were hauled in two trains of four, a train being pulled by one horse. Dumping was from a trestle about 20 ft. high constructed of round timber cut locally. The average haul was 650 ft. Temporary spur tracks were laid over the cut and the plowing done on each side of them. (It has been the experience of the author that, when the depth of cut is 4 ft. or more, it is economical to work at a face, undermining the earth, or plowing it with a sidehill plow, rather than working from the top. This is particularly true in hard material where a few light charges of powder will loosen a large quantity of material much more cheaply than with a plow.)

The labor costs on the car work were as follows:

1 foreman	$ 3.00
16 shovelers at $1.65	26.40
1 plow team and driver	7.50
1 horse and driver	3.50
3 dump men at $1.65	4.95
1 track man	2.00
Total per 10-hr. day	$47.35

The wheel-scraper work was nearly all borrow-pit work, the soil being easily plowed by a 3-horse grading plow. No. 3 Western wheelers were used. The daily labor force charges were as follows:

Foreman	$ 3.00
2-horse teams	5.00
3-horse snap teams	7.50
2 scraper loaders @ $1.75	3.50
Total per 10-hr. day	$19.00

The daily records showed that the cost by car, including the wages of carpenters building the trestle was 24.5 ct. per cu. yd., the average haul being 600 ft. The cost by wheel scrapers was 26.25 ct. per cu. yd., the average haul being 350 ft.

The plant required for the car work was as follows: Double track trestle, 24 in. gage, 6 ft. between centers of tracks, 6 x 8-in. stringers 22 or 24 ft. long, 2 x 6-in. ties on 2.5 ft. centers, 2 x 12-in. running boards between rails, 12-lb. rails, trestle legs of green poles averaging 30 ft. in length at 5 ct. per ft., cost complete $1.50 per lin. ft. of double track trestle, or $225 for 150 ft. erected; five split switches at $18, cost $90; two iron turntables at $30, cost $60; three ⅔-cu. yd. steel cars $190; total $565. Good for 5 yr. with 10% for repairs and renewals.

A Motor Truck Hauling Industrial Railway Cars. *Engineering and Contracting*, Aug. 2, 1916, gives the following:

A Four Wheel Drive truck is used in place of a locomotive to

draw a train of heavily loaded trailers on a narrow gage track. The truck itself straddles the rails, and it is interesting to note that enough traction is secured to pull the train easily up a 5% grade, although no load whatever is carried on the body of the truck.

The crushed rock, gravel and cement hauled by this outfit are being used in the construction of a 16-ft. concrete highway going north from Sioux City, Ia., on what is known as the Perry Creek road. The large amount of material hauled is indicated by the fact that from 500 to 600 lin. ft. of pavement are being laid daily. The track is four miles in length and ten round trips are made each day. Each trailer carries 1½ cu. yd. of gravel or crushed rock, making a total pay-load of 24 to 26 tons. The truck pulls this load while running in high gear, and travels at 12 to 15 miles per hr.

Fifty teams and wagons were unable to do the work which is now being done by this truck and string of trailers, according to the contractors, and an enormous saving in cost is effected. The average daily cost of operating the truck and trailers in this service is $17.

Hauling with Dinkeys. The ordinary "contractor's locomotive," or "dinkey," travels on a track of 3-ft. gage. The size of dinkey commonly used weighs 8 short tons, and is listed as having a tractive pull of 2,900 lb. on a level track. Whether the actual tractive capacity is exactly 2,900 I do not know; but it must be approximately that, for any locomotive can exert a pull of 25% of the weight on its driving wheels even on clean rails. The loads that a dinkey can pull, however, are much over-estimated in catalogues, due to too low rolling resistances assumed for cars.

It is said in some of the catalogues that the resistance to traction is 6½ lb. per short ton. This rate applies only to the best of standard gage railway tracks with heavy rails, well ballasted, and with heavy wheel loads. On a contractor's narrow gage, light rail track, the resistance to traction is probably not much less than 40 lb. per ton, and where the cars are loaded it is doubtless more, due to the dirt on the rails.

The resistance due to gravity is 20 lb. per short ton per 1% of grade; but, of course, the tractive power of a locomotive falls off 20 lb. for every ton of its own weight for each 1% of grade.

Based upon these data, and upon the assumption that the resistance to traction is 40 lb. per short ton, an 8-ton dinkey is capable of hauling the following loads, including the weight of the cars:

	Total tons
Level track	70
1% grade	46
2% "	33
3% "	26
4% "	21
5% "	17
6% "	14
8% "	10

Note: On a poor track not even as great loads as the above can be hauled.

Due to the accidents that frequently occur from the breaking in two of trains on steep grades, and from the running away of engines, it is advisable to avoid using grades of more than 6%.

When heavily loaded, a dinkey travels 5 miles per hr. on a straight track; but when lightly loaded, or on a down grade, it may run 9 miles an hr.

The following are the average struck measure capacities of the dump cars made by one firm (variations of weight of several hundred pounds occur, according to the make):

Capacity, cu. yd.	1	1½	2	2½	3
Weight, lb.	1,700	2,000	2,300	2,800	3,500

A car seldom averages its struck capacity of earth measured "in place," even when the car is heaped full with a shovel; for not only are there vacant places in the corners of the car, but the loose earth is 20% to 30% more bulky than earth "in place."

The number of dinkeys required to keep a shovel busy can be estimated from the data given. On short hauls (1,000 ft. or less) one very often sees only one dinkey serving a 1½-yd. shovel. In such cases the dinkey is not heavily loaded, so that it can run fast, and by having enough men to dump a train of 6 cars in 2 or 3 min., a fairly good daily output of the shovel can be secured.

In dumping the cars, estimate on the basis of one 3-yd. car dumped by each man in 1½ to 2 min. The men work in groups of 2 or 3 in dumping the cars, and enough men are usually provided on the dump to dump a train in 3 min.

When two or more dinkeys are serving one shovel, and long trains (12 cars) are being used, it would seem that very little lost shovel time would occur due to switching in an empty train; but, even under favorable conditions, I find that 1½ to 2 min. per train are lost in switching. This is another reason why a shovel served by only one dinkey makes so good a showing on short-haul work. Still another reason is that at the time the shovel is shifting forward, the dinkey can often make its round

trip; and on shallow face work this shifting of the shovel occurs frequently.

The method of using a hoisting engine and cable to move the cars is quite common in railroad work, where the hauls are short, say 1,000 ft. or less. The track is laid on a rather steep grade, at least 3% from the pit to the dump, and the cars coast down by gravity usually in trains of 4 cars holding about 2 cu. yd. each. The hoisting engines pull the cars back with a wire rope. A team of horses will have all it can do to pull a train of 4 such cars even on a slight down grade to the dump. As a matter of fact, a team that is working steadily can not be counted on to pull more than two cars holding 3 cu. yd. each, on a level track of the kind ordinarily used in contract work.

The 3-ft. gage track commonly used is laid with rails weighing 15 to 40 lb. per yd. of single rail. A 30 or 35-lb. rail makes a track that is not easily kinked under the loads, even when ties are spaced 4 ft. centers. A 6 x 6-in. tie, 5 ft. long, is the best size. I have tried 4 x 4-in. ties, but they are easily split by the spikes, and are not of much value after being used once; whereas the 6 x 6-in. ties can be laid 5 to 6 times. After the rails and ties are delivered, and the roadway graded, such a track can be laid for $200 per mile, or $4 per 100 ft., when wages are 30 ct. per hr. And the track can be torn up and loaded on wagons for $2 per 100 ft.; there being 1 ton of 30-lb. rails, and 375 ft. B. M. of 6 x 6-in x 5-ft. ties per 100 ft. of track.

Trautwine assumes that a contractor's locomotive will readily haul a train of 10 dump cars holding 1.5 cu. yd. each as a speed of 5 mi. per hr. He assumes 9 min. lost time each trip loading and dumping; and a train force as follows:

1 engineman	$ 3.00
1 dump foreman	3.00
3 dumpmen @ $1.50	4.50
½ ton coal @ $3	1.50
Oil, water, etc.	1.00
1 switchman	1.50
	$14.50

On these assumptions he figures that a locomotive in 10 hr. will haul as follows:

4,350 cu. yd. with a 1-mile haul.
2,700 cu. yd. with a 2-mile haul.
1,950 cu. yd. with a 3-mile haul.
1,500 cu. yd. with a 4-mile haul.
600 cu. yd. with a 10-mile haul.

Trautwine then makes a very serious error, for he entirely overlooks the fact that no steam shovel can load the full 4,350 cu. yd.

in a day that the locomotive might handle on a 1-mi. haul; and he fails to see that in reality the cost of hauling with a contractor's locomotive does not depend greatly upon the length of haul. In reality it matters very little whether the haul is long or short; for the steam shovel is the limiting factor, and a shovel may not average 500 cu. yd. per day.

In widening cuts on railway work it is often necessary to use flat cars holding 5 to 10 cu. yd. of earth, seldom over 7 cu. yd., unless drop sideboards are provided. A flat car is ordinarily 8.5 ft. wide over side sills and 32 ft. long over end sills.

In freezing weather the floors of the cars should be sprinkled with brine just before loading, a man with an ordinary garden sprinkler being detailed for the work. The brine will prevent the earth from freezing to the car floor for 3 or 4 hr.; but a loaded car should never be left standing over night, for it will take 4 to 6 men a day to unload a frozen car load of earth.

For costs of hauling with dinkeys and cars see Chapter XI.

General Types of Light Locomotives. Light locomotives are made to run by steam, gasoline, electricity and compressed air. There are many varieties of each of the four types.

Steam Locomotives burning coal are in most general use. Oil and wood burning machines are available. The Shay locomotive is a steam machine differing from the usual type in that instead of horizontal cylinders directly connected to the drivers, it has vertical cylinders driving a pinion wheel which in turn is engaged with gear on the driver. The result is an engine of great tractive force and slow speed.

Gasoline Locomotives are now being built and their use is increasing.

Electric Locomotives are useful wherever current can be obtained and used without danger. Both storage battery and contact type machines are used.

Compressed Air Locomotives are most useful in coal mines and in certain industrial works where there is danger of igniting gas or other combustible material. Their ultimate efficiency is low.

Resistance of Rolling Friction. According to the H. K. Porter Company's catalog, the resistance due to rolling friction varies with the character and condition of rolling stock and track. With extra good cars and track it may be as low as 5 lb. per ton of 2,000 lb.; but 6½ lb. may be taken for first-class cars and track, 8 to 12 lb. for reasonably good conditions, and as high as 20 to 40 lb. for bad cars and track, and 60 to 80 lb., or even more, for excessively hard-running cars and very rough track. Cars with wheels fast on axles and suitable bearings and oil boxes should not exceed 8 to 12 lb.; logging cars

HAULING CAPACITY OF DINKEYS

TABLE I. DIMENSIONS AND CAPACITIES OF PORTER LIGHT FOUR-WHEEL CONNECTED SADDLE TANK LOCOMOTIVES

Cylinders (diameter, in.)	5	6	7	8	10	12
(stroke, in.)	8	10	12	14	16	18
Diameter of driving-wheels, in.	18	20	23	26	30	36
Wheel-base, ft. and in.	3–0	3–6	3–9	4–0	5–0	5–0
Length over bumpers, ft. and in.	9–9	11–3	14–8	15–2	18–3	19–8
Extreme height (head-room not limited), ft. and in.	7–6	8–6	8–9	9–0	10–0	11–3
Weight in working order, all on driving-wheels, lb.	9,000	13,000	18,000	23,500	37,000	52,000
Water capactiy of saddle-tank, gallons	100	150	250	325	650	850
Fuel capacity (coal, lb.)	150	200	200	250	600	800
(wood, cu. ft.)	12	18	18	20	30	35
Weight per yd. of lightest rail advised, lb.	12	16	20	25	35	50
Radius of sharpest curve advised, ft.	20	25	30	30	45	45
Radius of sharpest curve practicable, ft.	12	15	15	18	25	25
Boiler pressure per sq. in., lb.	165	165	170	170	170	180
Tractive force, lb.	1,555	2,525	3,695	4,980	7,710	11,015
Factor of adhesion	5.80	5.15	4.88	4.72	4.80	4.72
Fastest speed for heaviest load, miles per hr.	3.6	3.85	4.25	4.65	5.2	6.0
Hauling capacity in tons of 2,000 lb. (exclusive of locomotive) extra good cars and track, 6½ lb. per ton resistance of rolling friction:						
On absolute level	230	380	555	750	1,165	1,665
Probable hauling capacity in tons on average construction track	38	63	92	125	194	278

may run 6½ to 12 lb. if of good construction, up to 20 or even 40 lb. if with poor arrangement for oiling. Contractors' dump cars are usually hard-running, say 10 to 25 lb.; coal-mine wagons, with loose wheels, are seldom less than 15 lb., and often exceed 30 lb. and with the holes in the wheels worn out of true, and the wheels scraping against the sides of the car, may develop 60 to 80 lb., or even greater resistance. Street cars may be reckoned at 15 to 25 lb. The resistance of flange friction on wooden rails is an indeterminate quantity, but usually twice the resistance on steel rails. Poorly laid track and crooked rails increase the resistance indefinitely. Overloading cars also increases the resistance greatly. The resistance is greater in cold weather. The resistance of rolling friction per ton is greater for empty cars than for loaded cars.

TABLE II. PERCENTAGE TABLE FOR APPROXIMATE COMPUTATION OF HAULING CAPACITY

Grades	Percentages figured to include Frictional Resistances per ton of 2,000 lb.					
On absolute level the percentage of hauling capacity is	6¼ lb. 100	10 lb. 65.	15 lb. 43.3	20 lb. 32.5	30 lb. 21.6	40 lb. 16.2
1% Grade	23	20.4	17	14.5	11.5	9.3
2% "	12.5	11.5	10.3	9.3	7.7	6.6
3% "	8.3	7.7	7.1	6.6	5.6	4.9
4% "	6.0	5.6	5.3	4.9	4.3	3.8
5% "	4.5	4.3	4.0	3.8	3.4	3.0
6% "	3.6	3.4	3.2	3.0	2.8	2.5
7% "	2.9	2.8	2.6	2.5	2.2	2.0
8% "	2.3	2.2	2.1	2.0	1.8	1.6
9% "	1.9	1.8	1.7	1.6	1.5	1.4
10% "	1.5	1.5	1.4	1.4	1.2	1.1
11% "	1.3	1.2	1.2	1.1	1.0	.9

To obtain the hauling capacity on any grade for track of any frictional resistance, multiply the hauling capacity of the locomotive on a level for a rolling friction of 6½ lb. per ton. (This is given in Table I) by the factor given above and point off two decimal places. The actual resistance of rolling friction may be determined by noting on what down grade a car once started will just keep in motion. If a car will hardly keep in motion if started down a 1% grade, its frictional resistance is just about equal to 20 lb. per ton; the same proportion will hold for other grades.

Water and Fuel Consumption of Locomotives. The number of gallons required per mile by a locomotive is approximately 1% of the total resistance to be overcome. The total resistance is expressed in lb. and is equal to 20 times the percentage of grade plus the rolling friction in lb. per ton, times the total weight of the train, engine, tender, cars and load expressed in tons of 2,000 lb.

The number of lb. of coal required per mile under the most

favorable conditions is very nearly the same as the number of gallons of water. Under unfavorable conditions as much as 40% more coal may be required. This relation of coal to water required is based on the assumption that 1 lb. of coal will evaporate from 5 to 8 lb. of water.

Filling in Flats with Dredged Material. (*Engineering News*, May 27, 1897.) In 1874 work was commenced at Boston for reclaiming the South Boston Flats, and this work consisted of the construction of seawalls and bulkheads of masonry, and the filling of the remainder of the area with dredged materials. The walls were packed with oyster shells and gravel, filling with a slope of 45% from the top of the wall. The material used for filling was stiff clay dredged from the harbor. This was distributed by small cars on tramways and trestles. The consistency of the material became semi-fluid by handling, weighing about 125 lb. per cu. ft., and great care was necessary in depositing near the walls, it being usually placed in a layer 4 or 5 ft. deep. This layer was left for several weeks in order that it might become consolidated while work was going on in other places.

Detailed descriptions of the methods used in 1886 for filling 120 acres are given by Mr. Frank W. Hodgon in *Journal of Association of Engineering Societies,* Vol. 7, page 5. The material used for filling consisted chiefly of blue and yellow clay with some fine sand and gravel in places. This was dredged from various parts of the harbor, placed in scows that were floated at high water over the area to be filled, and then dumped. This process was continued until the filling had reached a height of about 3 ft. above mean low water, that portion dumped being an average of 5 ft. in thickness.

To construct the remaining 10 ft. in height of fill the material was redredged from the scows, loaded on cars, and distributed on trestled tracks. The cars as a rule, held 7 cu. yd., but some held 10 cu. yd. The sides were hinged and the bottoms were shaped like an inverted V, so that half the material was dumped on each side of the track. The cars were first dumped along the entire length of the trestle in order to give stability to the piles supporting the trestle. Then dumping was commenced at the further end of the track.

The material after having been handled several times was in a semi-fluid condition and it assumed a slope 20 to 1 or 25 to 1. Great care was exercised to keep the dump moving as otherwise it would dry and set on the surface. Alternate parallel tracks were filled first in order to prevent the filling from forcing adjacent tracks out of line. Material dredged by scoops or dipper

dredges in the first place and then loaded into cars by clam shell dredges was broken up more and worked better than when first dug by and also loaded by clam shell dredges.

Attempts were made to place the material from cars that had been carried on scows and loaded directly at the dredging site, but this material was firm and would not run from the cars. Other attempts to carry the track directly on the dump instead of on a trestle failed completely because the tracks could not be held up.

The dump was leveled by men with wheel-barrows; 150 ft. from the track being about the economical limit of haul. Attempts at spreading the material with scoops drawn first by oxen and later by a hoisting engine and cable were also unsuccessful.

Cost with Horse-Drawn Cars and Portable Track. We are indebted to A. W. Sperry for the following data appearing in *Engineering and Contracting*, Oct. 14, 1908, regarding the use of steel Koppel cars.

Six to nine cars were used, of 36-cu. ft. capacity, running on a 24-in. gage track. These cars weigh 900 lb., and stand 4 ft. 2 in. above the top of the rail. They cost about $80 apiece. The rail was of 20-lb. section, costing about $30 per ton.

The excavation was made from a borrow pit alongside a railroad track, with the result that no ties were needed for the dirt track, but the rails were laid directly on the old ties and between the rails of the standard gage track. This is an economical method when lighter rails are used than those in the standard gage track, but, when the same weight rail is used in both tracks, then it is necessary to lay only one rail for the dirt track, using one rail of the standard gage track for the dirt cars. This effects a considerable saving in money in track. In all 2,000 lin. ft. of track were used.

There were 7,000 cu. yd. of material taken from the lower pit, and hauled an average of 1,000 ft., down grade, about one-half being a 2% grade and the other half a 4% grade. In making the fill, at times the rail was laid on grades as high as 8 or 10%. The cars would readily coast from the lower pit, and were drawn back by horses.

The material was a glacial deposit, containing from 15 to 20% of large boulders, fully 50% of which had to be blasted. The cost of blasting is included in the record of cost given below. These boulders prevented the material from being classed as earth. Under most specifications for excavation, the material would have been classed as earth and loose rock.

The cars were taken to the dump in trains, a brakeman being used on each train. Three to four horses working single, with

a driver, hauled the cars back to the cut. One man was also used on the dump, and he also attended to the track work.

A 10-hr. day was worked and the following wages were paid:

Laborers	$1.40 to $1.65
Brakemen	1.75
Dumpman	1.75
Firemen	3.00
Drillers	1.65
Single horse and driver	3.00

From 35 to 45 laborers were used on the work, from 3 to 6 drillers and 2 firemen. The firemen attended to the blasting. It was necessary to build a temporary trestle across a highway at a cost of $195.

The following is the cost per cu. yd. for each item of the work compiled from the total cost:

Loading cars	$0.215
Temporary trestle across highway	0.015
Drillers	0.035
Explosives	0.010
Dumpmen and track work	0.023
Horses and drivers	0.045
Brakemen	0.022
Freight and hauling on outfit	0.025
Depreciation of plant (about 7½%)	0.015
Superintendence	0.015
Total per cu. yd.	$0.420

Owing to the large number of boulders in this work, scrapers could not have been used in excavating the material. The boulders, too, were very hard on the cars; nevertheless the cars stood up well under the work. Owing to the down grade, the cars were much more economical in doing this work than either dump carts or wagons would have been.

The track work cost about $80 for this job, thus making an average cost of 4 ct. per lin. ft., or $210 per mile, of track laid and taken up; but it must be remembered that no ties had to be laid, as it was an "industrial track" made in portable sections.

It will be noticed that the cost of blasting was 4½ ct. per cu. yd. excavated, more than 75% of the cost being for the drilling. As there were only about 700 cu. yd. of boulders blasted, the most per cu. yd. for blasting for the boulders actually blasted was 45 ct. The hauling of the material cost nearly 7 ct. per cu. yd.

Taking into consideration the class of material excavated and the cost of blasting and the temporary trestle, the cost for the work is very reasonable.

Portable Railways in Road Construction. *Engineering and Contracting*, Mar. 4, 1914, gives the following:

For roadwork portable track is laid along the side of the grade or along the shoulders, and extends from the railway siding, gravel pit, stone quarry or other source of supply to the places where work is being done.

The equipment used on roadwork near Lockport, N. Y., consisted of about four miles of narrow-gage portable track, 40 (36- x 24-in.) dump cars and two 5-ton dinkey locomotives. The cars were hauled in trains of 12 cars each, the arrangement being so made that there was always one train of loaded cars on the way to the site of the work, one train of empties returning for material and one train of cars being loaded. The average amount transported was 80 cu. yd per day.

While hauling stone three miles from a crusher at the quarry to the road the cost of operating the trains was as follows:

Fuel and oil for locomotives and cars	$ 8.00
Labor:	
2 enginemen at $2.75	5.50
2 brakemen at $1.75	3.50
1 track foreman at $3	3.00
1 track laborer at $1.75	1.75
Totals	$21.75
Cost per cu. yd.	$0.272

As the material was hauled three miles the labor and fuel cost was 9 ct. per cu. yd. per mile. The average cost of grading the shoulder or berm of the road ready for track laying and laying track was between 2 and 3 ct. per foot of track.

Cost with a Light Railway on Road Work. The Easton Car and Construction Co. of Easton, Pa., furnish the following data on 18 miles of road built for the state at Bremen, Ind. The cars used are standard 1½ yd. capacity rocker dump car. Trains consisted of from 15 to 21 cars which weigh 1,400 lb. each when empty and hold 1½ cu. yd. of wet gravel weighing 3,100 lb. per yd. The average train is 20 cars or 60 tons on grades varying from level to 2% against the loads. The locomotive starts this load on a grade, as the grade is too long for a level start to do much good. Curves of 30 ft. radius are used, and the portable track is composed of 20-lb. rails on steel ties 3 ft. apart. This portable track is made in 15-ft. sections complete with steel ties and fish plates, so that a section may be easily handled by two men. One car in perhaps five or six is equipped with brakes on all four wheels, operated by means of standard brake mast and freight car type of hand wheel. The engineer on the job states that they make three round trips in a 9-hr. day, 7

miles each way, or 42 miles, which is an average of about 5 miles per hr., including delays for loading, switching and all other causes. They fill the 300 gal. water tank after each trip, although this is not necessary. It takes them 4 min. to fill the tank by means of a syphon which is always attached to the locomotive. They also fill the coal bunker which holds approximately 400 lb. after each trip, or three times each day; the consumption of coal in 9 hr. is therefore 1,200 lb.

The cost of hauling per day of 10 hr., the haul being 5 miles, is as follows:

(Average speed including time for coaling, taking water and coupling, 5 miles per hr. Actual time 8 to 10 miles per hr.)

Engineman	$ 3.00
Helper for switching and coupling cars	2.00
Coal, ½ ton at $4	2.00
Oil and waste	.50
Laying and taking up track at $50 per mile x 5 miles = $250 (150 average working days per season)	1.67
2 laborers on track	4.00
Interest and depreciation on outfit costing $12,000, at 20%, including repairs for one year based on 150 working days	16.00
Total per day worked	$29.17

Eight-ton locomotive will haul 20 loaded cars or more per trip, averaging 30 yd. on grades up to 2½%, and make 5 round trips on 5 miles haul in 10 hr., or haul 150 cu. yd. per day, equal to 750 cu. yd. miles; cost per cu. yd. mile, 3.9 ct.

Hauling Macadam Over a Portable Track in Ill. According to Fred Tarrant, in *Engineering News*, Feb. 18, 1915, two 20-hp. locomotives, 6 miles of portable track, and 1.5-yd. steel dump cars were used in the construction of a 12.5-mile water-bound macadam road, 10 ft. wide, in Illinois. Rails and ties were made in 15-ft. sections, weighing 225 lb. Two flat cars were used for hauling the track, but trains of dump cars coupled together with 6-ft. poles were better.

A track crew of four men could lay an average of 2,000 ft. of track per day. In order to keep the track in good alignment one man was required continuously to watch and correct low joints and loose connections.

By placing 10 to 12 cars ahead of the locomotive, and from 12 to 16 cars behind it — depending upon the grade — one locomotive could handle long trains. Where the grade was 4% or over, the engine dropped to the rear end of the train, and pushed the forward cars to the top of the hill, returning for the other half of the train later. Switching in the yard was handled by a mule. The equipment on one job was rented for 6 months, and in five months, 35,473 cu. yd. of broken stone

were handled, with an average haul of 3.17 miles, at a cost on the rental basis, including all the expenses and hauling both ways, of 14.8 ct. per ton-mile. This included also the necessary expenses for the equipment in first class shape. Team hauling on this job was estimated to cost at least 28 to 30 ct. a ton-mile.

Hauling Macadam Over a Portable Track in Mich. R. P. Mason, in *Engineering and Contracting*, Apr. 7, 1915, gives the following:

We had a very considerable stretch of macadam road to build and, in anticipation of a continuous program covering several years, a Koppel hauling outfit was purchased consisting of a 30-hp. locomotive, 50 cars, a tracklaying car and four miles of 24-in. gage portable track with curves and switches. This track is 20-lb. rail made up in 15-ft. sections with seven steel ties to the section. This unit is readily handled by two men. It is necessary to have track that is really portable and for this reason this type was selected.

Owing to the very narrow gage a low center of gravity locomotive is very desirable and the selection of the above type with the water tank beneath proved to be wise, as it kept the rails on occasions when a less stable engine must have capsized. The cars have roller bearings and are extremely easy running.

Our season's work was 9.5 miles of 16-ft. macadam 6 in. in depth compacted, laid in two courses, on what is known as the Manistique Trunk, or the road connecting Escanaba with Manistique.

We contracted for a sufficient supply of stone to keep the outfit busy to maximum capacity, to be delivered in hopper bottom cars; and I would say that this is a matter not to be overlooked, there must be a sufficient and constant supply of stone and, if shipped to the job, the railroad equipment must be in proportion and of proper and uniform type of cars to facilitate rapid unloading, or the efficiency of the work will suffer. The total output of a good sized quarry is required to keep this outfit busy and, as we have handled over 400 cu. yd. per day on short and medium haul, it is evident that no small crushing plant or undeveloped quarry would keep things going.

A loader consisting of a 24-ft. belt elevator carrying 16-in. steel buckets, driven by a 6-hp. gas engine, carries the stone from a pit beneath the standard track into two small bins — one for the large stone and one for screenings — the stone being deflected into the proper bin by a hinged door. A powerful winch with steel cable, driven by the same engine, is used to spot the cars,

both standard and small. The pit mentioned is fitted with a sliding door to control the flow of stone to the belt. The capacity of this loader is about 600 cu. yd. per day.

The portable track is laid under the bins with a siding to take care of the empty train. Suitable doors in the bins furnish the means of filling the train and the average time of filling a 25-car train is ½ hr. Train was supposed to be always loaded and ready.

Tracklaying is handled generally by three to four men and a car of steel is sent out as needed at the head end of the stone train, carrying 20 sections, or 300 ft. of track. As our day's macadam work seldom exceeded one-eighth of a mile, two to three cars of steel per day were sufficient. The track is laid on the shoulder after the grade is complete and made as permanent as possible, for it is found that it pays to have the track well leveled and solid in order to make time with the train. At least one man was kept going over the track constantly, especially in wet weather, to keep it in shape. As fast as any considerable section of the road was finished the track was thrown to the center of the road, the metal thus giving a perfect roadbed for the long haul.

The speed of the train was about 10 miles per hr., though that was not maintained as an average on account of a number of railway grade crossings where a watchman was stationed and where a short section of track had to be placed and removed for the passage of every train.

Trains of 20 cars were hauled on the start and five cars were added later, making 25-car trains, and it is the intention to haul 30-car trains this season, as we find that the locomotive will easily handle that many on our ordinary grades. Cars were loaded with 1¼ cu. yd. which, when dumped at a standstill, just made one course of the large stone. The loaded train is always pushed in order to have the locomotive back of the dumped stone. The haul was about 3½ miles each way from the set-up; season's average nearly eight trains per day and 236 cu. yd. per day of stone.

The spreading was done with a road machine hauled by two teams. When the cars were dumped there was always some stone left in them, but as the machine cut close to the cars, after the second trip the remainder was removed with a rake in a moment and the train was free to pull out. The unloading did not consume to exceed 10 min.

The road machine finished the spreading while the train was making another trip and a very little trimming with rakes left the road in perfect condition for rolling.

The crew required was about as follows:

Loader	4 men
Train	2 men, engineman and brakeman
Spreading	2 teams and teamsters
Spreading	5 to 7 men
Rolling	3 men
Sprinkling	2 teams and teamsters
Foreman	1
Watchmen	1 or more
Tracklaying	4

Wages were $2 per day for laborers, $5 for teams with teamsters, $3 for rollermen, engineman, $90 per month.

Compared with team haul the method described shows a saving of about 30 ct. per cu. yd., or nearly $700 per mile. We also save 39 ct. on our stone and 10 ct. on the unloading, making a total of about $1,800 per mile over previous prices. The saving on haul alone would be more marked on a longer haul. We also used the outfit in grading where material had to be moved some distance and found it extremely convenient and economical. Another very decided advantage of road building by this method is seen in the fact that there is no hauling over the road during construction and it is opened to traffic in perfect condition. It is also easier to keep the subgrade from being cut up and therefore takes less stone for a given thickness.

The following costs include everything that is a proper charge to the work, the cost of moving outfit from one point to another, laying up, and tracklaying includes taking up as well. Loading includes setting up loader and in one case building a siding 1,000 ft. long. The number of watchmen makes the hauling cost high; a greater output will cut down the spreading and the overhead in this case is high on account of the short season.

No. of days worked	93
Miles of finished stone	9.44
No. yards stone used	21,920
No. yards stone used per mile	2,310
No. days to build mile of road — average	9.4
No. yards stone per day	236
Cost of tracklaying per mile of finished road	$108.10

	Cost per cu. yd.
Cost of stone at our siding	$0.860
Loading trains	.052
Tracklaying	.047
Engineer	.020
Brakeman	.013
Watchmen	.017
Coal	.012
Oil, grease and waste	.002
Repairs	.003
Total	$0.114

Interest and depreciation on hauling outfit	$0.052
Spreading	.114
Sprinkling	.043
Rolling	.082
Foreman and timekeeper	.030
Total	$0.269
Interest and depreciation on all other machinery	$0.040
General expense	.031
Total	$0.071
Total cost per yd. (loose) of finished road	$1.418
Cost per mile	$3,275.58

Hauling with Gasoline Mine Motors. The installation of three gasoline mine motors to replace mule haulage in the entries of the mines at Walden's Ridge, Tenn., as described by G. E. Sylvester in *Mines and Minerals*, has displaced 23 mules and reduced the cost of hauling by 49.1%. All the extra work in the mine entry necessary for the installation of these motors was some slight trimming to give ample clearance and going over the track to replace with 20-lb. rail the places on the entry where a lighter rail had been used. The following is an abstract of Mr. Sylvester's article as published in *Engineering and Contracting*, May 31, 1911:

There was no difficulty found by reason of the many curves, as the motors have a 4-ft. wheel base and can take a curve of 25-ft. radius. The locomotives are 6 tons each and were built for the mine gage of 33 in. They are designed with 4-cylinder engines, of ample power to slip the wheels, and all parts are well protected, as is necessary for mine use.

The mine cars used are about 1,400 lb. in weight and carry 1.2 tons of coal. As the grade is in favor of the loads, the empty cars up the entry make the load for the motor. The regular 20-car trips are handled without difficulty, and on trial trips 40 cars have been taken up the entry.

The comparative estimate of mule and motor haulage on one entry is as follows:

COST OF COAL HAUL ON NO. 2 ENTRY, 1½ MILES OR 3 MILES FOR ROUND TRIP

10 twenty car trips equals	224 tons
By mules —	
4 drivers at $1.65	$ 6.60
9 mules at $0.50	4.50
Total by mules	$11.10

By motor —

1 motorman, per day	$2.05
1 coupler, per day	1.65
13 gal. gasoline at 11½ ct.	1.50
2 lb. carbide at 4 ct.	.08
½ gal. gasoline engine oil at 23 ct.	.12
1 gal. transmission case oil	.24
Total by motor	$5.64
Saving by motor	$5.46
Or, 49.1%.	

These motors use 12 to 13 gal. of gasoline each per shift. The gasoline tanks, of which there are two on each motor, are so placed in the frame as to be well protected in case of derailment or accident. The tank can only be filled when detached from the motor, and in changing these tanks it is necessary to have the valve closed. There are two extra tanks with each motor and these are filled on the outside. When brought into the mine they are perfectly sealed until after being exchanged with empty tanks on the motor. There is therefore no handling of exposed gasoline in the mine. The motors are made by the Geo. D. Whitcomb Co. of Rochelle, Ill.

Cost of Mine Haulage by Electric Locomotives. Mr. W. F. Murray is the author of an article on mine haulage appearing in *Engineering and Mining Journal* and in *Engineering and Contracting*, Feb. 27, 1907.

The following figures, abstracted from the latter account, show an actual comparison of cost of haulage by mules and by electric locomotives in a mine where 14 mules were replaced by one locomotive. The output of the mine averaged 1,500 tons per day for 245 working days per year. The cars weigh 2,400 lb. empty and hold 3,600 lb., making a total loaded weight of 6,000 lb.; 1,500 tons per day for 245 days makes a total of 367,500 tons yearly output.

Cost of Mule Haulage. Mules cost $180 each and harness $25 per set. The investment cost for mule haulage is therefore as follows:

14 mules at $180	$2,520
14 sets of harness at $25	350
Total	$2,870

Figuring annual depreciation at 20% and interest at 6% we have for interest and depreciation charges:

Depreciation on $2,870 at 20%	$574
Interest on $2,870 at 6%	172
Total	$746

It costs 50 ct. per mule per day for feeding, care and repairing harness. The wages of drivers are $2.80 per day. In addition, it is the custom in the West, where mule haulage is employed, to have a boss driver whose duties consist of directing the drivers to the different rooms, of seeing that the diggers have sufficient cars, etc. The boss driver's wages in this case were $85 per month. We have then:

14 mules 245 days at $0.50	$1,715
6 drivers 245 days at $2.80	4,116
1 boss driver 12 months at $85	1,020
Total	$6,851

The total tonnage hauled being 367,500 tons, we have by dividing this sum into the above totals the following costs per ton hauled:

Depreciation and interest on plant	0.20 ct.
Labor and keep of mules	1.86 ct.
Total per ton	2.06 ct.

Cost of Electric Haulage. Compared with mule haulage the investment in "plant" for electric haulage is high. The following are the figures:

Engine, locomotive, boiler and generator	$ 9,000
Switches, insulators and wire	1,200
Cost of erecting, etc.	1,000
Total	$11,200

The interest on investment and the cost of repairs and depreciation are as follows:

Interest on $11,200 at 6%	$ 672
Depreciation on boilers, engines, etc., at 9%	810
Depreciation on switches, wires, etc., at 5%	110
Repairs on boilers, engines, etc., at 9%	810
Repairs on switches, wires, etc., at 5%	110
Total	$2,512

The cost of labor and supplies are figured as follows:

Engineman at $75 per month	$ 900.00
Fireman at $85 per month	1,020.00
Motorman at $2.80 per day	686.00
Nipper on motor at $1.50 per day	367.00
Oil and waste	100.00
Sand	50.00
Total	$3,123.50

The total is too small by the amount of the cost of coal required to run the boilers. In reply to a letter calling the omis-

sion to Mr. Murray's attention, we are informed that the cost of the coal consumed must be charged to several items of work, such as pumps and fans, as well as to haulage, and that "after considering the cost of coal consumed the advantage is in favor of the locomotive." Taking the figures as they stand and dividing 367,500 tons into the totals, we have the following costs per ton hauled:

Depreciation, interest and repairs	0.68 ct.
Labor and supplies	0.85 ct.
Total	1.53 ct.

Comparison of Costs. A comparison of the two methods of haulage on the basis of cost per ton hauled gives according to the above figures the following:

Mule haulage, ct. per ton	2.06
Electric haulage, ct. per ton	1.53
Difference in favor of electricity	0.53

This difference would be somewhat less, it is to be noted, were the cost of fuel charged into the cost for electric haulage. In round figures, the saving by electric haulage in place of mule haulage is barely ½ ct. per ton, or for 367,500 tons a saving of $1,837 per year. In discussing these figures Mr. Murray says:

"These estimates, taken from an actual case, show a considerable difference in favor of electric haulage. The cost of installing mechanical haulage is greater than when a mine is supplied with mules; however, when we consider the cost of erecting a stable and the great loss due to mules killed in accidents, the initial expenditure is not so favorable to the use of mules.

"The chief advantage in using mules lies in the fact that the mule can enter any portion of the mine unhindered, while the locomotive cannot leave the trolley. Another fact worthy of consideration is the difference in weight of the rails that may be used in each system; by mule power, steel as light as 16 lb. can be used, while in other systems it is not advisable to lay less than 35-lb. rails. Also with locomotives an additional expense must be incurred, in bonding the rails.

Central-Control, Electrical Car Haulage. *Engineering and Contracting*, May 18, 1910, gives the following:

A considerable part of the clay excavated from the North Shore Drainage Canal, Chicago, will in time be used by the National Brick Co. for making brick. This company has the contract to remove the spoil banks for a part of the canal through the city of Evanston, Ill., and also has a contract for excavating another part of the canal known as Section 8A. At present the work of

excavation is going on at a rate required by the brick company to obtain only as much clay as it uses for the manufacture of brick. After the canal is completed the company will concern itself with the removal of the spoil banks left on other sections.

For the work of excavation proper, two 70-ton steam shovels are used and these are worked side by side in the cut and up against the dead end of the canal section. The distinctive feature of the plant is that the clay is hauled by motor-driven dump cars, moving in a continuous circuit and operated by a central-control electric haulage system. Car movements are controlled, except during dumping, by one man located in a tower in such a position as to command a general view of the work. This is one of the first applications of this system on contract work. It is claimed that the cost is not more than that of a haulage system of equal capacity equipped with locomotives (which latter would require at least three times the number of cars), while the cost of operation is materially lower than that for the locomotive haulage system. The equipment for this work consists of a power plant, 10 cars, and about a mile of narrow-gage track.

The power plant consists of a 55-KW. generator belted to a 60-hp. engine. This plant supplies current for lights and for power. The current is carried on a third rail, of 12 lb. section, which is placed in the center of the track. The tracks are of 30-lb. rail and 3-ft. gage.

The cars are of 3 cu. yd. capacity and their weight, when empty, is about 4,400 lb. Each car is equipped with a single motor of about 12 hp. capacity and with contact shoes taking current from the third rail. The motors are of special design, and each has in connection with it a solonoid brake which forms a part of the electric control system. The brakes and controlling mechanism are operated by current taken from the third rail at a reduced voltage from that for normal propulsion.

The track arrangement on which these cars are operated is merely a double track with a cross-over at each end. At the loading end the track ends in a 30-ft. stub lying between the steam shovels. The loaded cars pass from here for a short distance on level grade, but in rising out of the canal cut the track is on a temporary trestle laid at a 12% grade. The tracks pass along the bank of the canal to the brickyard and up again onto a trestle, where they are dumped by hand.

The novel feature of the haulage system is the control of all the cars by one man from a central point. The control of the cars consists of starting them from the shovel, bringing them up the incline and along the top of the canal bank to the dumping platform and starting them on their downward trip. In case of

emergency a car may be stopped or started on any portion of the track, but ordinarily the operation is continuous. Upon the down-grades the car is automatically governed as to speed, usually requiring no attention from the operator. The car by its momentum, on down-grade, becomes its own motive power and the motor becomes a generator. The motors are series wound and it is only necessary to reverse the armature connection to make them act as generators. A certain amount of resistance is mounted upon the car and so adjusted as to form sufficient electrical load upon the motor, working as a generator, to hold the car to a certain calculated speed. This operation forms the "dynamic brake" and will never allow a car under any condition to attain a greater speed on down-grade than this set speed. The conductor rail is divided into sections (separated by insulated joints), each section having independent connection with the controlling apparatus at the tower, or control station. Thus the cars on each section can be controlled independently of those on any other section. With more than one car on a section, however, all these cars are controlled as a unit. It is the duty of the tower man to keep the shovels supplied with an empty car at all times and so to distribute the empty cars on their return to the shovels that there will be continuous operation without "bunching" the cars.

The advantage of the operation of individual cars over that of trains is quite apparent. When one car is loaded it is not compelled to wait for the other cars to be loaded, as is the case where cars are hauled in trains. A car loaded at the shovel will be 1,000 ft. on its way before the next car is loaded. This makes it possible to keep all the cars working all the time and avoids keeping more than one car waiting for loading or unloading at any one time. It is claimed that this system operates with only one-third of the cars required when trains are used. Another advantage is that these cars, on account of their light weight as compared to a dinky engine required for a train, do not require as heavy rails nor so much labor to keep tracks in condition and ballasted as is required where engines are used.

The outlay for this equipment was about $28,000. During the first year the maintenance cost was abnormally high, due to the fact that no electrical man had been employed to look after the equipment. During the second year, however, a careful cost was kept on the maintenance and the cost given amounted to $505 for the entire year. The system used is the invention of Mr. F. E. Woodford, President Woodford Engineering Co., Chicago, Ill.

Cars Hauled by Cables. (*Engineering News*, May 21, 1903.)

On parts of the work of constructing the P. C., & W. R. R. in Ohio, the dump cars were hauled by cables from a hoisting engine. On one section four 3-yd. dump cars, weighing empty 2,500 lb. each, were pulled by a cable from a hoisting engine on the bank above and ahead of the shovel. The cars coasted down to the dump by gravity and were hauled a short distance to the trestle by a team. Much time would have been saved had a double drum engine, two cables, two trains, and a switch been provided.

On another section where the haul was 1,600 ft., one hoist was located above the shovel and the other one half way down the hill to the dump. Snubbing posts were used to guide the cable around curves. Two trains of 4 cars each kept the shovel busy, the waiting time which the loaded cars were being replaced by empties at the shovel being about 2 min.

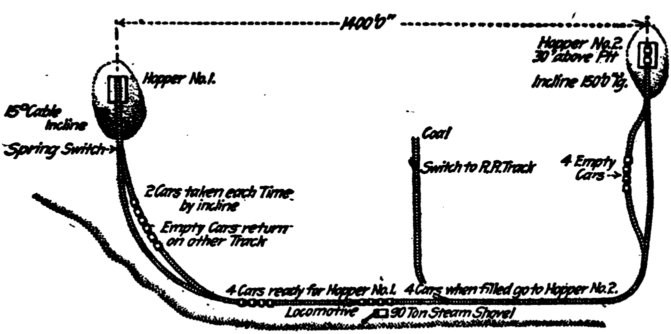

Fig. 10. Tramming System in Use at One of the Shale Pits of the Purington Brick Co.

Tramming System Used in a Shale Pit. According to *Engineering-Contracting*, Mar., 1906, a highly economical tramming system for steam shovel work has been in use at Galesburg, Ill., in one of the shale pits of the Purington Paving Brick Co.

In this work the dinkey locomotive occupies a position intermediate between two trains of cars which deliver two ways to the bottom of two machines leading to the hoppers of the clay machine at each end of the pit. The cars are of 2 cu. yd. capacity each, and the locomotive keeps 20 of these going, tramming them alternately in teams of six and four cars two ways to the ends of the pit, whence they are hauled, two at a time, to the hoppers. When empty the cars run down by gravity and are switched automatically to the empty track.

Spotting Cars. A device shown in Fig. 11 is used to haul cars into position at the shovel. This consists of a long cylinder and piston into which exhaust steam is admitted. The amount of steam and time consumed in moving cars a short distance, from 5 to 7 ft., with this device is so small as to be negligible.

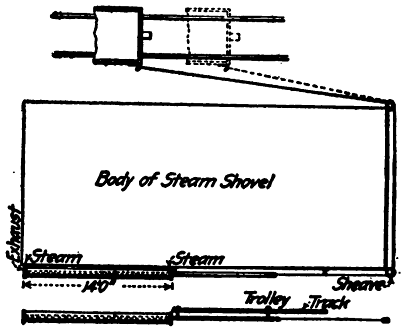

Fig. 11. Device Used for Spotting Cars.

Steam Shovel Work. A 90-ton Marion steam shovel, of 5 cu. yd. dipper capacity, but fitted with a 2 cu. yd. capacity dipper was used. With this, digging from a 50 ft. bank an average of 17,422 cu. yd. of shale was handled per month of 26 9-hr. days, or 670 cu. yd. per day. It is estimated that this is less than one-half the amount that could be handled were the shovel digging loose gravel. As it is, the shovel is digging only one-third of the time. The material was delivered to twenty 2-cu. yd. cars, trammed two ways, 1,500 ft. and 2,000 ft. respectively, to bottom of two inclines, and then hoisted by cable to an elevation of 20 ft. above the track and dumped into the hoppers of the machines.

The cost per month of 26 working days of 9 hr. each for the steam shovel work is shown in the following table:

1 engineman	$110.00
1 crane man	85.00
1 fireman, 22 ct. per hr.	52.65
3 track men (shovel), 17½ ct. per hr.	128.85
1 locomotive engineman	80.00
1 switchman, 20 ct. per hr.	46.80
*2 hoistmen, 20 ct. per hr.	93.60
39 tons coal, for shovel, $2	78.00
13 tons coal (locomotive), $2	26.00
26 tons coal (hoist), $2	52.00
Total per month	$752.90

* Hoistmen dump the cars.

As 17,422 cu. yd. of shale were handled per month, the labor and fuel cost per cu. yd. was 4.3 ct. The charges for superintendence, oil, waste and incidentals are not included in the above estimate; adding these the cost per cu. yd. amounts to practically 5 ct.

A Cable Haulage Plant. In *Engineering News*, Jan. 21, 1904, is an article describing the plant of the Bronson Portland Cement Co. in detail.

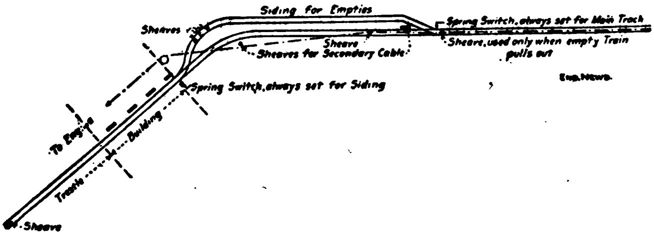

Fig. 12. Sketch Showing Track Arrangement at Mills.

The marl used in the manufacture of the cement is dredged from under water by a dipper dredge, equipped with a 1½-yd. bucket and digging to depths of 30 ft. The dredge loads directly into cars. These cars were formerly drawn by horses but the increased capacity of the plant required a more rapid method of transportation. As the marsh was overlaid by a 2 to 5-ft. layer of unstable muck the use of heavy engines was impracticable, so a cable haulage system was installed.

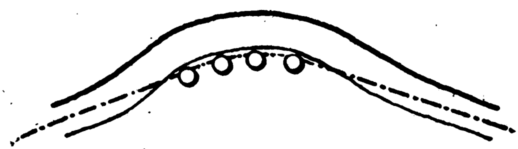

Fig. 13. Sketch Showing Manner of Carrying Haulage Rope Around Curves.

The 1½-yd. steel dump cars are hauled in trains of ten or more, being "spotted" from the engine room in accordance with signals by rope and bell made by a trip rider. Fig. 12 shows the arrangement of the tracks and Fig. 13 the method used in carrying the haulage cable around the curve.

The full width of the dredge cut is excavated on one side, the track being laid as the cutting proceeds. Then the full width is

excavated on the other side. Finally, by means of a float or barge made of oil barrels to hold the empty cars, the space where the track was laid is excavated, taking all the territory an entire width of 175 ft. for each track.

The hauling engine is a double 10- x 16-in. cylinder engine. The rails weigh 35 lb. per yd. and are laid on 8-ft. cedar or tamarack ties. The haulage cable is of ¾-in. plow steel, the haul rope being 5,500 ft. long, and the tail rope 1,100 ft. long. As may be seen, the track leads up a trestle inclined at a grade of 6.37° to the mill. At the top is a track large enough for 12 cars, descending at a 1% grade into the building. Alongside this is a side track for empties. The cars are drawn into the building by a separate tail rope cable. When the cars reach a point directly above the bins, the tail rope is quickly disengaged and immediately attached to the empty train, the short tail rope cable being attached at the same time. The haulage rope is likewise transferred, and the empties are pulled out without delay. The loaded cars are dumped by two men, and the cars washed out with a jet or hose. These cars after being dumped are hauled to the siding by passing the rear short cable around a sheave on the side track.

The force required is as follows: Dredge, 3 men; trip rider, 1; track cleaner, 1; dump-men, 2. An average of 1½ men in addition is required for laying and removing track. Ten cars are loaded in from 6 to 10 min., and a round trip about 6 min. The output is about 30 cars or 50 cu. yd. per hr. More than 60,000 cars were delivered in 8 months.

Life of Cable on an Engine Incline. The life of a ¾-in. wire cable used to haul cars on an incline operated in connection with steam shovels on the Chicago Main Drainage Canal was 150,000 cu. yd. of solid rock, cars being hauled 350 ft. horizontally and 60 ft. vertically. Details of the methods and cost of that work are given in Chapter XVI of Gillette's "Rock Excavation."

Flat Car Unloaders. Flat cars are ordinarily unloaded with an unloading plow designed for the purpose. The car carrying the plow or scraper is attached to the rear of the "mud train" of 10 to 30 cars. One end of a 1¼-in. wire cable is hooked to the plow and the other end, which is attached to an ordinary car coupling link, is coupled to a car or to the engine. Usually this cable is 400 ft. long and extends over 12 cars. The brakes on all these 12 cars are set tight, and the engine is started with the forward cars if there are more than 12 in the train. If the rear 12 cars are pulled along, blocks are laid on the track to hold them, or a few cars may be chained to the track. The engine moves ahead at a rate of 2 or 3 miles an hour, until the plow

has traveled the length of the 12 cars, and the material is thus scraped off the side of the cars. The engine is backed up a few feet, when 4 to 6 men throw the cable off to one side. Then the remaining full cars are backed up to the last half empty car where the plow is, the cable is coupled to the engine and the plow pulled forward as before. The plow is left on the last car which is unloaded by the next train. The time of unloading is 10 to 30 min., average 20 min., the engine doing as much in that time as 8 or 10 men would do in a day.

When unloading on curves the time is longer, for snatch blocks must be used to keep the cable on the cars. A snatch block

Fig. 14. Side Unloader. Made by Marion Steam Shovel Co., Marion, Ohio.

every third car is generally enough. The cable passes over the snatch block sheave, and the block is held with a chain passing over the side of the car, and fastened to the bolster or arch bar of the car. When the plow reaches a snatch block it must be stopped, the block and chain being removed and carried forward. Unloading this way takes about twice as long as on straight track.

When much material is to be handled on flat cars, two things should be done; (1) the cars should all be rigged with hinged sideboards that can be dropped down when unloading, for then a car will carry 14 cu. yd.; (2) and a hoisting engine should be rigged upon a car by itself for the purpose of pulling the plow

cable instead of using the locomotive for that purpose. A 10- x 12-in. double cylinder engine with a 1-in. cable for loose gravel, $1\frac{1}{8}$-in. for heavier material, will unload a train of cars often in half the time taken by locomotives, since the cars need not be blocked or chained to the track, and there is little danger of breaking the cable as often happens where a locomotive pulls the plow. Furthermore, since this unloading engine on its car is a part of the "mud train," it can do the unloading while the whole train is moving ahead, and thus spread the material along a greater length of track.

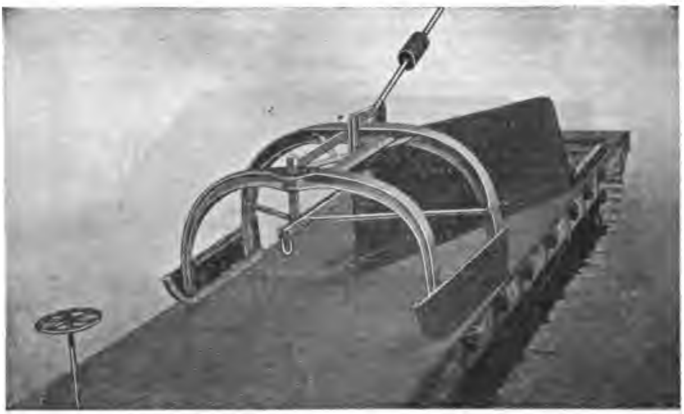

Fig. 15. Center Unloader. Made by Marion Steam Shovel Co., Marion, Ohio.

After the material is unloaded by a plow alongside a track it can be most economically spread with a leveler or spreader. This spreader is a car provided with projecting side wings which can be raised by a winch when not in use.

The spreader car is loaded with 5 to 15 tons of scrap to hold it to its work, and moves at 6 to 10 miles per hr., thus leveling off a ridge a mile long in 6 to 10 min. Ordinarily the spreading is done by the last train before the close of the day, but in freezing weather spreading must be done oftener.

Hauling and Unloading on the Panama Canal. In 1908, according to *Engineering and Contracting*, Aug. 26, 1908, the Panama Canal Commission had 27 unloading plows in use. These were of the right hand, left hand, and center dump, types. Used in connection with them were 18 Lidgerwood unloaders.

From the Culebra Cut to the Tabervilla dump, trains of 17 cars were used to carry earth and rock. These trains were loaded under the shovel and carried directly to the dump without being made up a second time, the distance being 16 miles. On June 23, 54 of these trains were unloaded by four unloaders in 8 hr., handling a total of 17,280 cu. yd. This is at the rate of 4,320 cu. yd. per machine, being 540 cu. yd. handled per hr. for each machine.

The canal commission used four styles and sizes of cars: The large Lidgerwood flats, 20-yd. Western side dumps, 12-yd. Western and Oliver side dumps and the old French 6-yd. dump cars. The Culebra or Central division in order to reduce their loads to place measurement allowed the following loads per car:

Lidgerwood flats, 20 cu. yd.
20-yd. Western dumps, 17 cu. yd.
12-yd. Western and Oliver dumps, 10 cu. yd.
6-yd. French dumps, 5 cu. yd.

One train made up of 12-yd. Western dump cars hauling from Culebra to Mamei dump, nine miles, loaded, hauled and dumped 294 cars in 6 days, being 3,528 cu. yd. loose measurement or 2,940 cu. yd. place measurement. This meant 490 cu. yd. place measurement handled by this train a day. This was the highest record made by a train using these cars and running to this dump. With a train made up of 12 cars, this meant 4 round trips per day, or a distance of 72 miles traveled in 8 hr. by the train. The efficiency of the larger cars is shown by the fact that a train of 24-yd. flat cars, making a haul of 16 miles, carried to the dump 960 cu. yd. place measurement per day, as compared to 490 cu. yd. place measurement with 12-yd. cars on a nine mile haul.

Methods of Handling Unloader Plow Cables. In *The Rose Technic*, Oct., 1903, Wm. S. Hawley has an article on grading railroads which contains a description of a method used for unreeling an unloader plow cable.

A Lidgerwood unloader engine operated the 1½-in. plow cable. This was long enough to stretch over 30 cars. To unreel the cable its end was attached to a chain stretched across the track between two piles. These two piles were driven about 14 ft. center to center, one on each side of the track, with their tops about 8 ft. above the rails. A short length of chain, the ends of which were hooked together when the cable was ready to be unreeled, was fastened to each pile. After the cable had been fastened to the chains the train moved forward, thereby pulling it out.

The cars held 12 cu. yd. each, and there were 15 cars in a

train. Each car had a wooden apron, one end of which rested on the next car, thus forming a continuous floor over which the plow traveled. The material, after being dumped, was leveled by a spreader with air-operated wings. This machine leveled to a distance of 18 ft. from the center of the track.

In *Engineering Record*, Feb. 17, 1900, the construction of the Jerome Park Reservoir is described. A 50-hp. engine operated a Lidgerwood plow used for unloading the cars. The train generally consisted of a flat car carrying a Lidgerwood unloader engine, followed by an empty car at the front end, after which came 12 cars holding 120 tons of rock or earth, and finally at the rear end, a flat car carrying the plow. The train was drawn onto one of five parallel tracks which were spanned by a wire cable stretching between the tops of two 30-ft. posts guyed to deadmen. A second and parallel cable was stretched 5 ft. below the tops of the posts, and the two cables were connected by vertical ropes to the center of the track. Another short manila rope with a loop at its lower end was attached to each vertical tie. When the drum of rope on the car reached a point beneath the cable the end of the plow rope was hooked on to the manila rope, the train moved forward, and when the plow reached the same point, the cable was detached from the loop and attached to the plow. The plow was then drawn forward until it reached the empty car in the rear of the unloader. The 12 cars were unloaded by this method in about 5 min.

Recommendations for Using Cars on Steam Shovel Work. *Engineering and Contracting*, May 1, 1907, gives the following:

In the report of the Committee on Roadway, of the American Railway Engineering and Maintenance of Way Association, the following questions were asked and answered. *How many Pitmen?* From three to eight are recommended; but under ordinary circumstances the committee recommends four men.

Would it be advisable to have shovel made to swing back of the jack arm so that cars can be loaded in tunnel or rock work where entrance is narrow and cars cannot be pulled beyond shovel? Replies in favor, 13; against, 23.

Form of Shovel Track. "T" rails on ties are mentioned by 12 members, chain rails are mentioned by 5 members, rails on stringers are mentioned by two members. The committe recommends "T" rails on ties.

Length of Pieces for Ordinary Work. The replies vary from 3½ to 6 ft. The committee recommends 6 ft.

What Form of Joint. The replies are as follows, viz.: Strap, 27; chair, 5; lap, 2; link and pin, 1; hasp, 1; U-bolt, 1. The committee recommends strap joints.

What Gage of Track for Dump Cars? Standard, 32; narrow, 3. The committee recommends standard.

What style and capacity of cars, namely, dump cars, flat cars, cars with sides for plows and unloaders or other special forms, would you prefer for the following kinds of work? (1) Cut under 6 ft., haul less than one mile: Replies to circular letter all, except one, favor the ordinary Contractors' Dump Cars, with varying capacities. The committee recommends 6-cu. yd. dump cars. (2) Cut under 6 ft., haul one to six miles: 6 members favor 5-yd. dump cars, 2 members favor 12-yd. dump car, 3 members favor standard flat car, 9 members favor standard car, with permanent sides. The committee recommends standard car with permanent sides with swinging hinged doors and cars connected by aprons. (3) Cut under 6 ft., haul six miles or over: 7-yd. dump car is recommended by 5 members, 30-yd, dump car is recommended by 1 member, standard flat car is recommended by 14 members, car with permanent sides is recommended by 10 members. The committee recommends same car as given in connection with (2). (4) Cut over 6 ft., haul not less than one mile: 9 members favor 5-yd. dump car, 3 members favor 12-yd. dump car, 1 member favors 15-yd. dump car, 9 members favor standard flat car, 10 members favor standard car with permanent sides. The committee recommends 6-yd. dump car. (5) Cut over 6 ft., haul one to six miles: Replies received all, except one, favor either standard flat car or standard car with permanent sides. The committee recommends car described under (2). Cut over 6 ft., haul over six miles: 8 replies favor dump cars varying from 5 yd. to 30 yd. capacity; 12 are in favor of standard flat car and 9 recommend standard car with permanent sides. The committee recommends car described under (2).

The committee recognizes the fact that the standard commercial flat car must frequently be used, and when this is necessary, especial care should be taken to cover certain important matters: (1) See that the car is strong enough for the purpose. (2) Note that brake-wheels are in good condition, and in case material is to be plowed off, these must be placed at side of car. (3) Care should be taken that stake pockets are in good condition and not spaced too far apart. Four feet apart in center of car and closer at ends is considered good practice. (4) See that the stakes are strong enough to prevent accident or derailment of plow.

Where dirt is dumped from trestle in fill for haul less than two miles, would you use light cars and light trestle or heavy cars and strong trestle? 15 replies favor light cars and trestles,

12 replies favor heavy cars and trestles. The committee recommends light cars and light trestles.

Has your experience with unloading plows, using cable, been satisfactory? 31 ayes, 6 noes.

Would you handle cable by locomotive or an auxiliary engine and drum, and if the latter, give kind and size? 3 members recommend locomotive and 32 auxiliary engine. Sizes of drum vary from 3 ft. to 5 ft., two members recommending each 3 ft., 4 ft. and 5 ft. sizes, one member 3½ ft. and one other 4½ ft. Engines are mentioned as 10 x 12 and 12 x 12, 60-ton and 25 hp. The committee recommends handling cable with an auxiliary engine and drum. The machine should be able to develop 60-ton pull and will weigh about 28 tons. Steam cylinders 12 x 12 in., and diameter of drum, 4½ ft., which will permit four wraps of 1½ cable to be made.

When raising track do you prefer center plow for unloading or two side plows used alternately? 29 replies recommended center plow and 6 the use of side plows. The committee recommends that when raise is light, the center plow be used, but that side plows are more advantageous in making heavy fills.

Has your experience with reversible plow been satisfactory? Ayes, 1; noes, 12. The committee does not favor its use.

The Lloyd Unloading Machine. This device, described in *Engineering and Contracting*, Oct. 2, 1907, is used for filling high embankments from dump cars. The general arrangement, Figs. 16 and 17, consists of a circular track at the head of the bank, around which the cars are operated by a cable and from which they are dumped. From the center of the unloader radiate large timbers which support the track, and which rest on iron rollers placed several feet apart and riding upon wooden sills on the top of the bank. At the center is a mast from the top of which steel rods support the ends of the radial timbers. Near the mast is a hoisting engine which operates the cable for hauling the cars. After the train has been uncoupled from the locomotive and hitched to the cable it is pulled around the track and dumped while in motion. Material can be dumped at any point either inside or outside making it possible to fill from 40 to 70 ft. wide. The unloader is moved forward by its own power, 10 ft. at a time. The force required consists of engineer, carpenter, and 3 laborers. The advantages of this machine on high fills are:

(1) The dispatch with which it handles trains;
(2) Low cost of construction as compared to cost of trestle;
(3) Ease of erecting and dismantling.

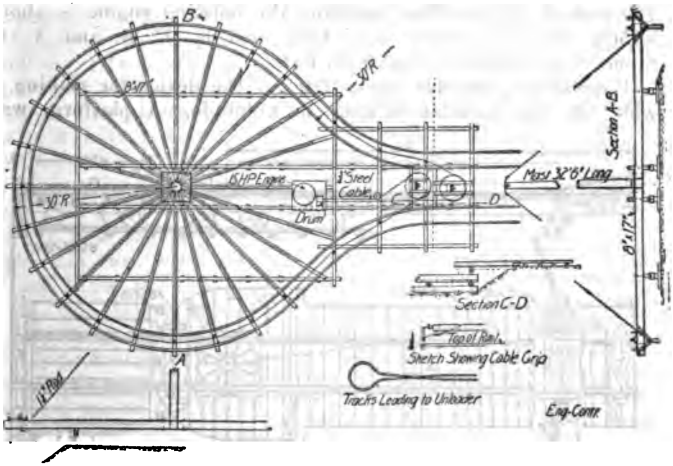

Fig. 17. General View of Continuous Car Unloader.

Fig. 16. Plan of Continuous Car Unloader.

The cost of the machine including the hoisting engine is about $5,500. These machines have been used by E. B. and A. L. Stone Co., Contractors, Oakland, Cal.

A Swinging Platform Dump Track. The device for making a wide fill was used at a mine in Colorado. A platform was

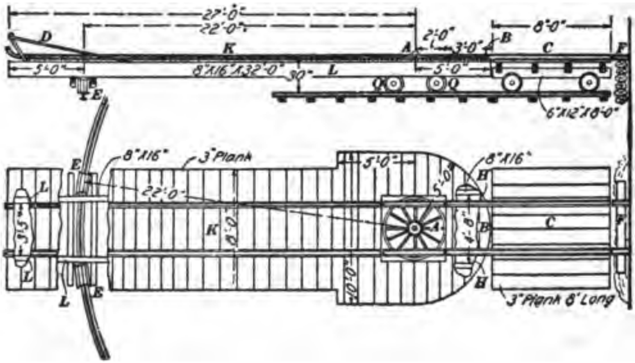

Fig. 18. Plan and Elevation of Swinging Dump Track.

pivoted to swing laterally so that a dump 57 ft. wide could be built without shifting the main track. Two men moved cars to and from the dump by hand, and dumped them at the rate of 100 per day. The swinging truck was composed of 2 pieces of 8 x

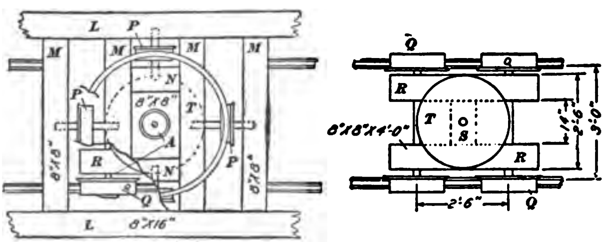

Fig. 19. Details of Turntable and Truck.

16-in. x 32-ft. pine upon which was laid a platform of 3-in. planks carrying the rails. The rear end was supported on a 4-wheel truck upon which it pivoted; the outer end was supported upon wheels travelling upon a rail of 22-ft. radius leaving a 5-ft. overhang. End dump cars were used.

Comparative Cost of Handling Earth on Flat and Dump Cars. According to *Railway Age Gazette*, June 18, 1915, the cost of handling earth on flat cars was 100% greater than the cost of handling it on dump cars, in work on the new passenger terminal and belt line at Kansas City. Over 2,000,000 cu. yd. of earth and rock were removed and handled on flat cars and on 12-yd. Western air dump cars. For two months the cost of handling material with these two types of equipments was kept in two files. The material during these two months consisted of approximately 75% solid rock.

The flat cars were wooden construction, capacities of 60,000 lb. and 80,000 lb., and had been in constant service of 18 months at the time this information was collected. In justice to them, it should be said that the repairs increased the average cost by approximately 1.5 ct. per cu. yd. The dump cars were of steel frame construction; of 80,000 lb. capacity, and had been in service 5 months. The cost of engine service includes the rental of the engines and the pay of the fuel, from the time of their arrival to the time of their departure of the trains at the dump.

One great advantage of the dump cars over the flat cars was that it was found possible to unload at the end of a spur track on the fill successfully, with the dump cars; while this could not be done with the flat cars and unloader plow, because the plow at the end of the train occupied a space of at least 20 ft. Furthermore, it was impossible to do little loading on the main

COST OF HANDLING MATERIAL ON FLAT AND DUMP CARS FOR TWO MONTHS

First Month

	Flats	Dumps
Car repairs	$ .071	$ .001
Engines	.082	.024
Lidgerwood and airman	.005	.007
Labor on cars	.027	.009
Labor on truck	.084	.066
Engineering and superintending	.004	.004
Miscellaneous	.010	.003
Total	$0.282	$0.114

Second Month

	Flats	Dumps
Car repairs	$ .070	$ .007
Engines	.075	.024
Lidgerwood and airman	.004	.008
Labor on cars	.034	.008
Labor on track	.093	.057
Engineering and superintending	.004	.005
Miscellaneous	.006	.004
Total	$0.286	$0.113

track by means of this unloader and plow, because of the danger of delay of construction trains and traffic. On the other hand, trains of dump cars were frequently sent out to unload a few minutes ahead of passenger trains, with only slight danger of delaying them.

Dumping Cars with Derricks. (*Engineering News*, Aug. 24, 1905.) This method was devised by W. J. Newman. The spoil from the Chicago tunnel was delivered in 4-cu. yd. capacity cars, mounted on 24-in. gage trucks, by electric locomotives to the dump at Grant Park. Small 4-wheel dinkeys hauled the cars to a 75-ton derrick of 40 tons capacity, with a 65-ft. boom. The bottoms of the cars were so arranged that when released they fell clear away from the sides, thus presenting no obstacle to the dropping of the sticky clay. A car body was lifted by the derrick, dumped, and placed back on its underframe. Very high dumps could be made.

Removing Sticky Material from Dump Cars. *Engineering and Contracting*, Sept. 25, 1907, gives the following: In excavating for a foundation at New York City part of the spoil was dumped into seagoing scows. The spoil was conveyed to the dock in 3-yd. wooden side-dump cars and loaded by means of a stiff-leg derrick with 60-ft. boom seated in the edge of the dock. The pivots on the car trucks were removed and the car bodies were used as skips, being lifted over the scows by four chains attached to their corners.

The excavated material was sticky and tenacious and some difficulty was encountered in getting the cars to dump clean. This trouble was done away in the following manner: The original dumping arrangement of the cars consisted of one long side hinged by bars from each end pivoted in the centers of the end walls and operated by hand levers. These levers were removed and the lower edges of the hinged sides provided with latches to lock them shut and with rings engaging the hooks of two of the hoisting chains. In dumping, the boxes are lifted from the cars and set on the deck of the scow, the chains slackened and the latches opened. When the hoist is again operated the chains first open up the revolving side and then lift the box, revolving it until the open side is down and all the contents are discharged.

A Method of Unloading Cars to Bins in a Small Space. *Engineering and Contracting*, May 3, 1911, gives the following:

Fig. 20 illustrates a hoisting tower located over the material track adjacent to bins. A clamshell bucket is operated in the hoisting tower to raise the material from gondola cars to a point in the tower above a swinging chute. The chute is automatically swung under the bucket so that the discharged load falls from

the bucket to the swinging chute and from there is guided to its proper compartment in the bins.

The former method for loading the bins was by means of a bucket conveyor which carried the material from a pit below street level. The material was dumped into the pit through a grating from wagons. This method would have been possible at the present location of the plant if bottom dump cars could

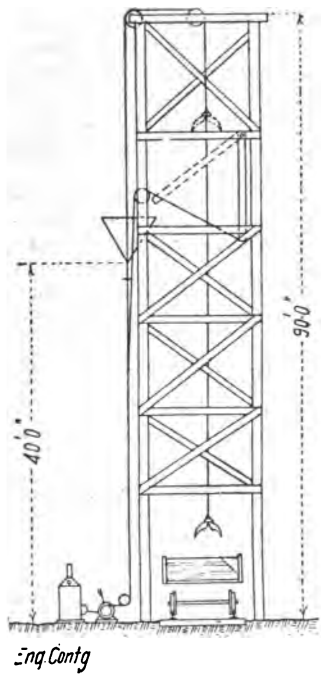

Fig. 20. Arrangement for Unloading Cars into Bins.

have been secured, but as this could not be guaranteed the new device was gotten up.

From 8 to 10 cars are unloaded per 8-hr. day, allowing for time lost for switching and moving the cars for the clamshell. Three men are used in the car to locate the bucket and an engineer and fireman are required to operate the double drum engine and boiler. The cost of the labor is estimated as follows:

3 laborers at 37½ ct. per hr.	$ 9.00
1 engineer at 75 ct. per hr.	6.00
1 fireman at 37½ ct. per hr.	3.00
Total per day	$18.00
300 yd. average per day, per yd.	$ 0.06

The plant and methods were worked out by Mr. J. K. Thompson, who is superintendent for the contractors.

Unloading Cars by Sluicing. J. C. Lathrop, in *Engineering News*, Sept. 25, 1913, describes a method of unloading cars of sand, gravel, and cinders, employed by him in the construction of a fill near Akron, Ohio. By means of water pumped by a 20-hp. motor-driven pump from a canal, 400 or 500 ft. away, the material was sluiced from hopper-bottom cars to any point within 150 ft. A 4-in. pipe line, with suitable valves, and 100 ft. of 2½-in. hose was used.

The best method was to fill a car with water, then open the bottom gates, and, with a jet from the hose, wash the material into galvanized iron chutes leading from a point beneath the car to the place of deposit. Two men could unload a car 40 cu. yd. of sand or loam in 2 hr., and of cinders in 3 to 4 hr.

One decided advantage gained by the sluicing method was solidity of fill.

The comparative cost of unloading cars by water jet and by hand was:

Unloading 10,000 cu. yd. (250 cars) by water jet:

1,000 hr. labor at 20 ct.	$200
Labor installing and removing pipe electrical connections, pump and motor	225
Depreciation of plant (assumed)	100
Current, 1,000 hp.-hr. at 2 ct.	20
Total at 5.45 ct. per cu. yd.	545

Unloading and spreading 10,000 cu. yd. by shovels and scrapers:

5,000 hr. labor at 20 ct.	$1,000
1,600 hr. team and driver at 60 ct.	960
Total at 19.6 ct. per cu. yd.	$1,960

Spreaders. Spreaders pushed by a locomotive are often used in connection with car unloading plows. Fig. 21 shows a spreader, made by the O. F. Jordan Company of Chicago.

A ditching device for use with this spreader is shown in Fig. 22. It is claimed that this can be operated at the rate of 8 to 12 miles per hr. in shallow cuts and that two or three trips through the cut are sufficient to form the ditch. In deep cuts the material is forced into a pocket back of the plowing edge

which holds 6 to 10 cu. yd. The material is wasted at the end of the cut or on a fill.

Cost of Spreading with a Jordan Spreader. Mr. S. T. Neeley in *Engineering News*, August 9, 1906, gives the cost of spreading material dumped from 12-yd. Western dump cars. The

Fig. 21. A Jordan Spreader at Work.

spreader cost $2,400, and the engine, which was only partly employed in this work, cost $2,200.

The daily cost per working day was as follows:

Interest and renewals	$ 2.00
Engine runner and fireman	5.50
2 laborers at $2.25	4.50
Fuel, etc.	5.75
Total per day	$17.75

The cost per rainy day and holiday was $8.50, giving a total cost per month of $440, or a cost of 1.4 ct. per cu. yd. for 30,800 cu. yd.

Engineering and Contracting, July 24, 1912, in an article on four-tracking the New York Central and Hudson River R. R., gives some data on using a Jordan spreader. On this work dumping was done from the main track until the embankment to hold a construction track had been built. The traffic was very heavy on this road, so no more material was dumped from the main line than was absolutely necessary. Train loads of 150 to 200 cu. yd. were dumped and spread (using a narrow wing on the spreader), in 6 to 8 min. When from 12 to 15 min. were available the large wing was used, and the earth was spread to the full working depth of the spreader.

If the spreader is taken care of it should be sold at the end of 15 years for a reasonable price.

The machine can easily handle all material which can be supplied by trains which might be anywhere from 1,000 to 20,000 yd. per day.

The first cost of the spreader was $5,000.

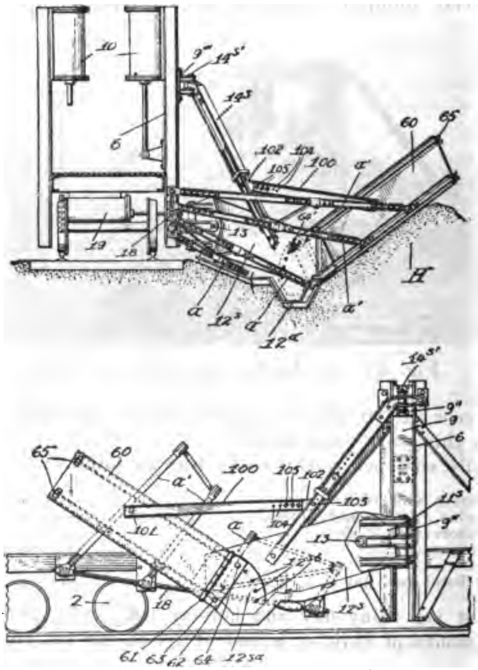

Fig. 22. Ditching Attachment for Jordan Spreader.

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CHAPTER XI

METHODS AND COSTS WITH STEAM AND ELECTRIC SHOVELS

Types of Shovels. There are so many different designs of power shovels in use that it is extremely difficult to make a complete classification. For the purpose of study of costs the following classification seems sufficient.

1. Non-Revolving Shovels.
   a. Standard Railroad Shovel.
   b. Traction Shovels mounted on broad-tired wheels or caterpillar treads, or on "feet" as in the so called walking dredge.
2. Revolving Shovels.
   a. Heavy Stripping Shovels carried on two parallel tracks.
   b. Standard gage Railroad Revolving Shovels including the so called Railroad Ditchers.
   c. Small Revolving Shovels mounted on wheels, skids or caterpillar treads.
3. Miscellaneous Excavating Tools of the Shovel Type.

How to Handle a Steam Shovel Plant. Mr. E. A. Hermann's excellent monograph on this subject is now out of print, but we are indebted to his work for some of the following suggestions.

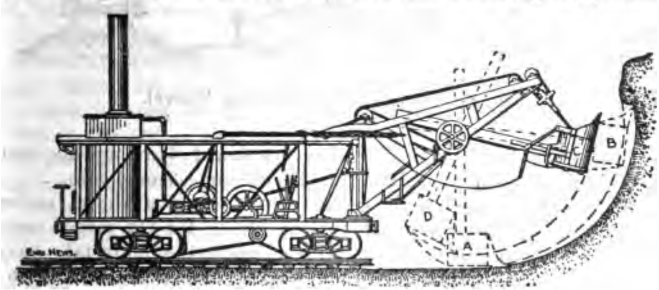


Fig. 1. Side View of Steam Shovel.

Figs. 1 and 2 show the general features of the types of machines designed to run on tracks. It will be noted in Fig. 2 that jacks are used at the sides to brace the machine. A revolving shovel can dispense with these jacks.

Operation of Steam Shovels. All movements of the dipper are usually controlled by two men, the cranesman and the engineman. The engineman operates the levers that cause the raising or lowering of the dipper and the swinging it right or left. The

cranesman regulates the depth of cut made by the dipper, releases it from the bank when full, and trips the latch of the bottom door when ready to dump the bucket. These two men must learn to work in perfect unison, for the output of the shovel depends very largely upon their combined skill. After dumping, the bottom door latches by its own weight when the bucket is swung down and back ready for the next scoop. In loose gravel a bucketful can be loaded every ½ to ¾ min., in hard materials, 1.5 to 2 min., but one would make a grievous blunder were he to figure the daily capacity of a shovel on any such basis, for there are always delays in moving the shovel forward and placing the jacks which has to be done about every 4 or 5 ft., delays in "spotting" cars ready for loading, etc. The laying of a new

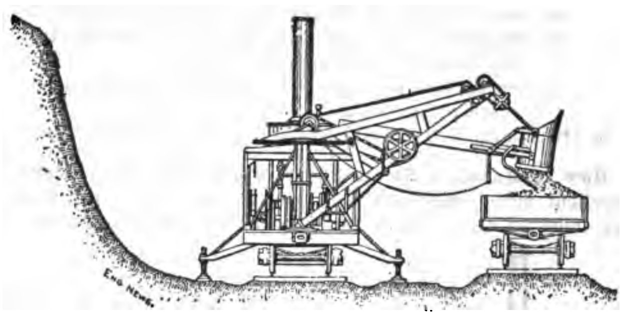


Fig. 2. Front View of Steam Shovel.

section of track, moving the shovel forward 4 ft. by its own power, and jacking up will ordinarily consume 3 or 4 min.

The width of the cut or swath excavated by a shovel varies from 18 ft. for the smaller shovels to 120 ft. for the larger ones. The depth of a cut depends largely upon the material; easy running sand or gravel might be worked almost to any depth; sidehill cuts in loose gravel up to 300 ft. in height have been taken. There is danger in such cases of a slip that will bury the shovel. Cuts 60 ft. deep are common in gravel pits. In average material cuts of 25 to 30 ft. are common, while in hard tenacious material the cut should not be deeper than the height to which the dipper can be raised — that is, 14 to 20 ft. Where cuts are very shallow the ordinary steam shovel cannot work economically at all, although the small revolving shovels seem better adapted to shallow cuts than any of the others.

Beside the cranesman and the engineman there are usually a

fireman, a blacksmith, a blacksmith's helper, two to five car repairers, and four to ten laborers. In average soil four laborers are enough, but in tough material that must be broken down by wedging or blasting ten and sometimes more are needed.

For breaking down the bank in front of the shovel the men are provided with a 16-ft. hickory or ash pole, shod with a pointed spike.

The blacksmith and helpers are provided with a portable shop, forge, etc.; their principal work consisting in repairing side boards, chains, etc., on the cars.

Higher Cost in Shallow Cuts. The reason for the increased cost in shallow cuts is quite apparent if one stops to "figure," but in deepening the Erie Canal, for example, where the cut was only 1 to 2 ft. deep, we have seen steam shovels used by contractors who evidently had not stopped to "figure" beforehand — they did their "figuring" afterward, to their sorrow.

If a shovel could excavate a block 18 ft. wide by 2 ft. deep by 4 ft. forward, each move, it would excavate less than 3 cu. yd. before a move would be necessary. Obviously the bucket would go out about half full each scoop, but even assuming that it were full, and held 1 cu. yd., we see that more than half the shovel time would be spent in moving forward. If the shovel load were ½ cu. yd., which is higher than the average in such a shallow cut, the shovel would be doing useful work about 2.5 hr. out of the 10.

Widening Railway Cuts. This is a class of work for which steam shovels are so often used that we shall consider the methods of attack in some detail.

Before the shovel can begin work it is generally necessary to excavate a section of the cut, *AB*, Fig. 3, 30 to 50 ft. long, using wheelbarrows, scrapers or the like. The switch *AB* is laid off the main track for the shovel to travel upon, and the "mud train," of 10 to 20 flat cars, is drawn up on the main track ready to be loaded. The shovel is moved forward as soon as all the material within reach has been loaded, and to do this short sections of track 4 to 6 ft. long are provided. These sections are usually moved by attaching them to the dipper with a chain, and dragging them from the rear to the front. When the shovel has moved forward the length of a full rail, 30 ft., rails are laid to extend the switch so as to keep it close to the shovel. This is particularly desirable where the bank is apt to cave, for then the shovel can be moved back if caving is anticipated.

Since railway hauls are usually long it seldom pays to have less than two locomotives with trains, and unless automatic dump cars are used two trains will be found economic even on short

hauls of ½ mile or so. This, however, is a matter that the contractor or engineer may quickly determine by a little observation in each particular case. Three engines and crews will be needed for hauls of more than 10 miles, or where the traffic on the main line is so great as to cause many delays in moving the "mud train." A contractor in estimating the cost of widening railway cuts must be careful to allow liberally for delays due to traffic on

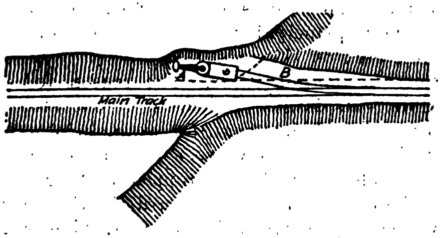


Fig. 3. Shovel Widening Cut.

the main line, which may be 40 to 70% of the working 10-hr. day.

As shown in Fig. 2, the track on which the shovel runs should be a foot or two lower than the main track, not only to provide for material that drops off the cars and that washes in from the sides of the cut, but also to drain the ballast on the main track.

Where the traffic delays do not exceed 5 hr. out of the 10

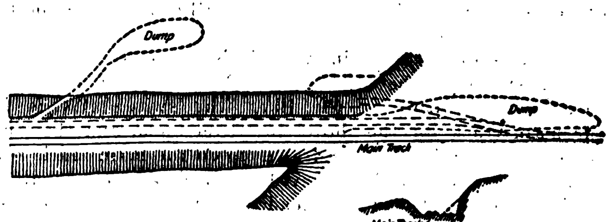


Fig. 4. Arrangement of Tracks.

working hours it is generally considered more economic to work as just described, but when the delays become more frequent, another method must be employed.

A narrow cut is first made by hand shoveling so that a switch track for the "mud train" may be laid, Fig. 4. In doing this hand excavation, flat cars are often loaded by men with wheelbarrows, but this method is slow since only a very small

gang of men, 6 to 10, can be worked at the face of the cut. Three to six flat cars are run out on the side switch, and a plank runway laid on the end car nearest the face of the work. The men load the car farthest from the face first. The author would suggest that a "locomotive crane" or traveling derrick moving back and forth on the main track could be used to excellent advantage instead of wheelbarrows for work of this character; and in soft material, if provided with a clam-shell bucket, such a traveling derrick could be operated with very little hand shoveling at all. Upon the approach of a train, the traveling derrick can rapidly move to the side switch back of the mud train. Instead of flat cars, contractors' dump cars may be used and drawn away by horses to the dump, or one-horse dump-carts may be used. The work is too confined for scrapers to be used.

After the narrow cut has been made, the side track is laid and the steam shovel run in on a second switch shown in Fig. 4.

Cutting Down Railway Grades. It often becomes necessary to cut down railway grades at summits, when methods of attack differing from the foregoing must be adopted. Fig. 5 shows the most common method of attack where the mud train is on the main track. It will be noted in Fig. 5 that the steam shovel track is on blocking, the grade of its track being about 2 ft. below that of the main track which is about as low as a small shovel can work and dump into the cars. The blocking is made of 6- x 12-in. x 4-ft. sticks upon which 12- x 12-in. track stringers are laid, and the track is kept level. This blocking is generally 5 ft. high, for a small shovel can usually dig only 5 ft. below the track it runs upon; thus it will be seen that the depth of each slice or cut is only $5 + 2 = 7$ ft.; and, as shown in Fig. 5, the successive cuts are parallel with the old main track grade until the last cut is made to final grade. This shallow cutting and blocking up of the shovel track make the work somewhat more expensive than ordinary.

The engineer in fixing a new grade should have in mind the fact that it is cheaper to make an even number of full cuts of say 7 ft. each than to plan so that a fractional part of a full cut must be made.

Some shovels cut fully 8 ft. below their track instead of 5 ft., and for extensive work of this kind are evidently far more economic. Figs. 6, 7 and 8 show various cross-sections of cuts.

It should be noted that a steam shovel cuts a 1 to 1 slope, whereas the finished side slopes must often be 1.5 to 1. In that case the shovel can either undercut, as in Fig. 7, or it can supercut, as in Fig. 8. Undercutting is the most economic for no more material is moved than is necessary; and the rains will

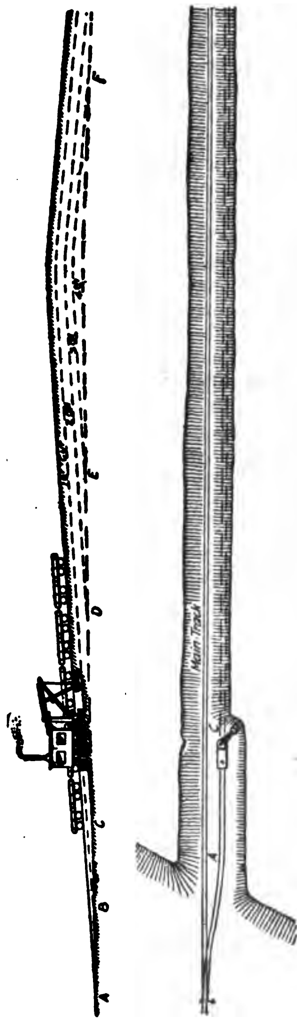


Fig. 5. Use of Steam Shovel in Cutting Down Grade.

slough off the upper part of the cut until the desired permanent side slope is obtained. But if the work is super-cut, the slopes must be trimmed by hand, which is an expensive method.

Where traffic is very heavy a temporary side track must first be built, as described under Widening Cuts. Fig. 9 shows such a

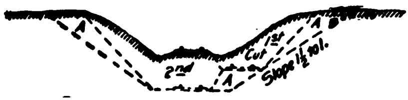


Fig. 6. Cross Section of Cut.

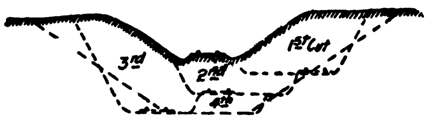


Fig. 7. Cross Section of Cut; Shovel Undercutting.

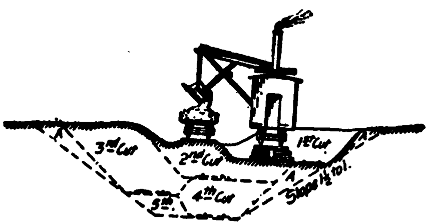


Fig. 8. Cross Section of Cut; Shovel Super-Cutting.

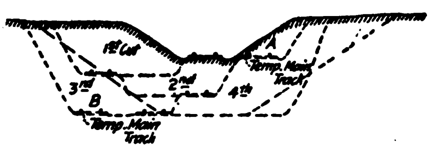


Fig. 9. Cross Section of Cut. Using Temporary Main Track.

temporary track at A. If the depth of the original cut exceeds the height to which the dipper can be raised, and if the material is so tenacious that it cannot be broken down by the men with bars, then cuts are made as in Fig. 10, where L L are the temporary loading tracks.

On double track railways the traffic may be diverted to one of the tracks while the other is used for the "mud train."

It will be seen that each cut must be studied as a separate problem, the object being to secure the necessary deepening with the fewest possible number of "swaths" or cuts.

Railway Construction Work. Where an entirely new cut is to be taken out, the work may be attacked in a way somewhat different from the widening or deepening of existing cuts. There are two methods of attacking a new cut: (1) The through-cut

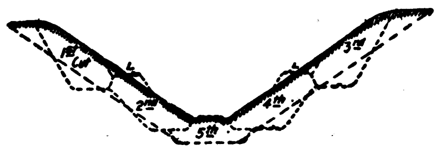


Fig. 10. Using Temporary Track in a Deep Cut.

method; or (2) the side-cut method. The work that we have just been describing comes under the side-cut method; that is, the cars are loaded upon a track laid alongside of the shovel and in advance of it. The through-cut method is shown in Fig. 11, from which it will be seen that the loading tracks are carried through at the same time with the shovel track. One of the loading tracks S^1, is often dispensed with, although the work is

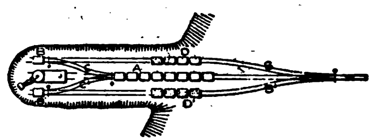


Fig. 11. Through Cut Method on New Construction.

greatly facilitated by having two cars, B and B^1, always on hand to be loaded.

In through-cut work only contractors' dump cars can be used, since it is obvious that a flat car could not be run up far enough to be loaded. Moreover, the frequent moving of the cross-over tracks, C and C^1, makes it important that the track be a light one.

The great objection to the side-cut method is that the grade of the natural ground is generally so steep that a side-track cannot be laid over which a locomotive can travel, and to get a side-track through the shovel often has to do a lot of dead work,

as shown in Fig. 12, where the shovel is shown in the act of cutting down the top of the hill so as to make a trackway for the loading track.

Wheel scrapers, or the like, can in many cases be used in such a case, and the material may be wasted off to one side or put in the fill, if the haul is short. Where a track can be laid at once on the natural ground, or where such cutting as is shown in Fig. 12 is small, the side-cut method is of course to be preferred since the cars are more quickly "spotted," that is, placed alongside the shovel ready to be loaded.

Where the through-cut method is used, as in Fig. 11, either a team of horses is used to spot the cars, or a light 4-hp. hoisting engine with cable may be used, the engine being generally stationed on the bluff in front of the shovel. Some contractors

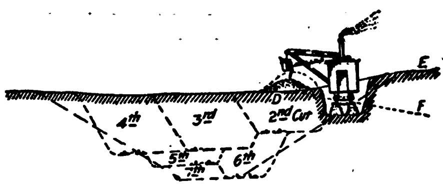


Fig. 12. Side-Cut Method on New Construction.

use an extra locomotive for spotting the cars, and upon the whole that is the best method.

If the steam shovel used is of the traction type, weighing about 35 tons, it can readily climb the summit of most hills that are to be cut down, and attack the work there by the side-cut method, providing the cars can be moved over their track. A dinkey locomotive will climb a 10% grade with 4 empty cars, so that if the grades are greater, the only methods remaining are to load into wagons, or to use a hoisting engine to pull the empty cars up and let the full ones down to the dump.

By providing snubbing posts against which the wire cable rubs, such a cable may be used for long distances (1,000 ft.) even on curves; and by using a second hoisting engine to take the cars when the first reaches the "end of its string," distances up to nearly half a mile may be covered. Where cables are used in this way on the side-cut method, a train of 4 to 6 cars is usually operated, and the track must be laid on a grade of at least 1.5 to 2% to insure that the cars will start and run down by gravity. Each train of cars is pulled up past the shovel, and the last car loaded first; then the hoisting engineman slacks on his brake and

lets the cars "down a notch," so that the next one can be loaded.

There is always some lost time in dropping the loaded cars out of the way and getting up a train of empties, even where a double-drum engine is used, but the shovel can be moved forward during this interval and so reduce the lost time. The cable method is not as economic as the use of contractors' locomotives, and is not used where it can be avoided.

Canal Excavation. We come now to a class of work that usually differs considerably from railway excavation. In modern canal work the material taken from cuts is not used to make fills, but is wasted. This generally makes an entirely different method of attack necessary, for while the upper part of the excavation can be taken out by the side-cut method, as the excavation in-

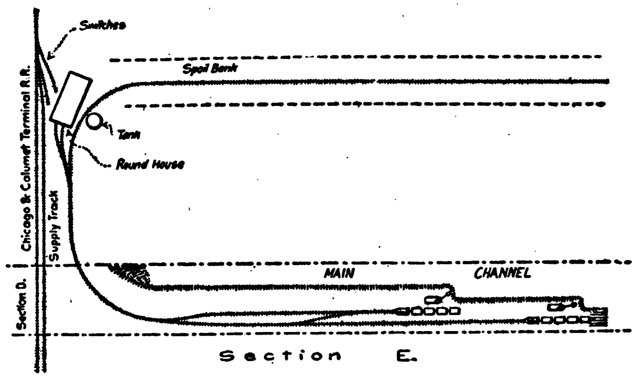


Fig. 13. Arrangement of Track on Chicago Drainage Canal Work.

creases in depth a time is reached when locomotives cannot climb the grades necessary to get out of the canal prism to the waste dumps. Since the shovels do not have to make frequent moves from hill to hill as in railway work, a larger type of shovel can be used; but there is no gain in using larger shovels unless large cars can be delivered rapidly enough to keep the shovel busy, or unless the material when blasted breaks up in such large chunks that a small shovel cannot handle it at all.

Figs. 13 and 14 show arrangement of track on two sections of the Chicago Drainage Canal work. Cars were handled with contractors' locomotives. Both these examples illustrate the use of the side-cut method of excavating the upper part of a canal section.

When the depth of the cut reaches a point where the locomo-

tives cannot move the trains up the incline, it becomes necessary to install a hoisting engine plant, using a cable to pull cars up the incline.

The cars may be loaded by the side-cut method as before, and run to the foot of the incline either by locomotives or by teams of horses, and there hoisted by the engine. At the top of the incline, either horses or a locomotive may be used to haul to the dump.

Since the hoisting engine must be moved when the haul to the shovel becomes very long, the hoisting engine may be mounted on a platform car 18 x 40 ft., running on a very wide gage track. A 13 x 16-in. double-drum engine has handled 2,500 cu. yd. per

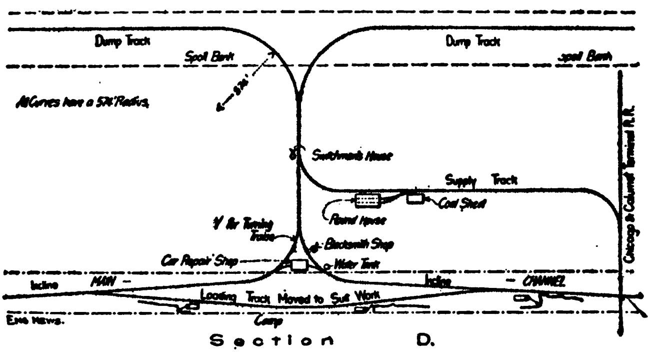


Fig. 14. Another Arrangement of Track, Chicago Drainage Canal.

10-hr. day on one of these inclines. As such a plant costs only $3,000, and is very flexible, being easily adapted to any particular kind of work, it is evidently meritorious. Where an incline serves only one shovel, instead of two, a much smaller engine will evidently serve.

Fig. 15 shows the arrangement of tracks for use with such an incline. It will be noted that the tracks on the dump are so arranged that the loaded cars can be run on track A, so as to pass the empty cars returning on track B.

By using locomotives instead of horses to handle the cars it would not be necessary to move the incline often, unless it were to keep down the investment in rails and ties.

D. J. Hauer, in *Engineering News*, Dec. 31, 1903, calls attention to the fact that through cuts and grade reductions work are more expensive with a steam shovel than widening cuts, the first class of work mentioned being the most expensive of the three. For

through cuts, especially where they are small, requiring frequent moving, a 35- to 45-ton shovel is to be preferred, as it is more easily moved and its 1 to 1½ dipper will fill cars as fast as they can be shifted. But 65- to 95-ton shovels are better on grade

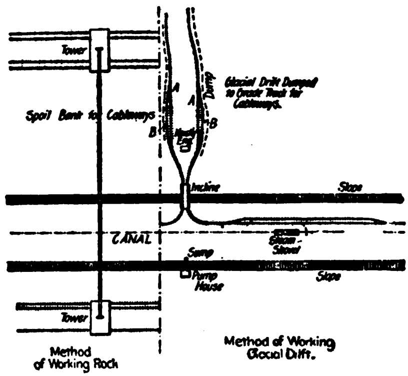


Fig. 15. Tracks Used with an Incline.

reductions and double tracking, because they can be moved on the existing track. They can be easily supplied with coal and water and more readily served with cars.

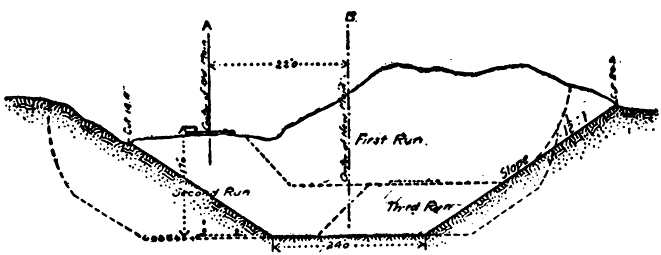


Fig. 16. Cross Section of Steam Shovel Excavation (Solid Lines Show Intended Final Cross Section; Dotted Lines Show Section Actually Cut by Shovel).

S. T. Neely, in *Engineering News*, Aug. 9, 1906, describes a job where a 65-ton Bucyrus shovel, loading 12-yd. Western dump cars, took out the first cut to a depth of 9 ft. below the top of rail of loading track as shown in Fig. 16.

Attention is called to the fact that such a deep excavation is too deep for the fastest work, and that the first cut was so large as to require excess excavation in the remaining cuts. A program of excavation is suggested in Fig. 17 which would obviously have been more economical.

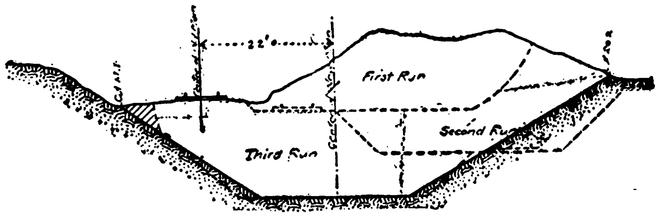


Fig. 17. A Better Method of Excavating Cut Shown in Fig. 16.

Making a Steam Shovel Cut of Two Lifts in One. This is described in *Engineering and Contracting*, Mar. 2, 1910, by H. Morton Stephens.

The work on which this was done was in North Carolina on the Southern Ry. The outfit used consisted of two model 60 Marion shovels, seven dinkeys, cars, rails, etc. The shovels were started at opposite ends of the work, one of them being moved a distance of 9 miles in 10 days over dirt roads.

The first two cuts taken out by one shovel contained about 52,000 cu. yd. and were taken out in the usual 8 ft. lift manner. The specifications of the railroad company called for a 20-ft. roadbed and 1 to 1 slopes in cuts, and would not allow the contractor for the additional width made necessary by the use of a model 60 shovel, which requires, when using a dinkey track in the bottom of the cut on the last lift, a 26-ft. roadbed.

As the remaining six miles allotted to this shovel were all practically two-lift cuts, averaging about 13 ft. in depth, and as some of the cuts were about 3,000 ft. long, it was apparent that some scheme had to be devised whereby this extra unpaid for material would not have to be moved.

Upon investigation it was found possible to raise the boom on the shovel by simply taking out the links or loops in the boom support guy rods or hog rods, at the end where they are attached to the yoke at the apex of the A-frame. It was also found necessary to make two plates to fit on the rim of the swinging circle, at the corners of the aperture in the same under the boom, in order to reduce the angle and prevent the cutting of the cable

which operates the swinging circle. This raising of the boom, etc. was accomplished in about two hours.

The shovel then started in on a single track cut about 3,000 ft. long, with an average depth of 9 ft. The deepest cut was 15 ft., and was taken out in one lift by lowering the dinkey track 1½ ft. With the boom raised in this manner it was possible to dig a 13½-ft. lift; and when cuts are, say 16 ft., it is possible to take them out in one lift, by excavating a trench for the dinkey track about 3 ft. deep. The material coming from this trench is placed inside the slope stakes, and later taken out with the shovel.

By this method one trackage layout is sufficient for a cut of the above nature. There is no moving back, and there is very little extra material taken out even with a roadbed specified to be only 20 ft. wide. The shovel is a little faster acting with the boom raised, as described, and there is no additional wear and tear on the machinery.

The material encountered was almost all stiff clay, with a small amount of loose rock. This shovel has averaged about 25,000 cu. yd. per month, and has only had one breakdown, this being a very small matter.

Cost of Steam Shovel Work. Shovels are so designed that about 3 dipperfuls can be averaged per minute when actually loading cars; but the author finds that even with well arranged tracks, and a good high face, the necessary delays of shifting the shovel ahead, switching the trains, moving the shovel back to start a new swath, etc., keep the shovel idle about half the time. Occasionally, under exceptionally favorable conditions, a shovel may average 6 or 6½ hr. of actual shoveling per 10-hr. day.

The size of the dippers, as listed in catalogues often refers to dippers heaped full of loose earth. The actual "place measure" averages about 30% less than the listed capacity of a dipper, for not every dipper goes out full, and, even if it does, the earth is not as compact in the dipper as in place.

On the basis of 3 dippers loaded per minute of actual work, we have the following for dippers of different sizes:

—— Dipper —— Nominal,	Actual (average)	— Output in Cu. Yd. — Steady Shoveling	
Yd.	Yd.	10 hr.	5 hr.
1	0.7	1,260	630
1½	1.0	1,800	900
2	1.4	2,520	1,260
2½	1.7	3,060	1,530

We see that where the shovel is actually shoveling 5 hr. out of the 10 (and this is a good average), a 1-yd. dipper will load 630 cu. yd.; a 1½-yd. dipper, 900 cu. yd.; a 2½-yd. dipper, 1,530 cu.

yd. However, the track arrangement must be such that cars are promptly supplied to the shovel, if any such average as 900 cu. yd. per day per 1½-yd. dipper is to be maintained.

Taking the 1½-yd. dipper as the common size, we may say that in "average earth," with cars promptly supplied, 900 cu. yd. are a fair 10-hr. day's work; but if only one dinkey is used, the lost time may easily be increased to such an extent that 650 cu. yd. become a good day's work in "average earth." In hardpan, or exceedingly tough clay, the output of a shovel may fall to about half the output in "average earth"; that is, 450 cu. yd. per 10-hr. day with a 1½-yd. shovel.

The size of shovel to select for any given work depends upon the yardage of earth in each cut — not upon the total yardage in the contract. On very light cuts, such as street and road work, cellars, etc., a small shovel with a ½ to 1-yd. dipper is usually most economic. Use a small 26-ton traction shovel, with 1-yd. dipper for small railway cuts, where moves from one cut to another will be frequent. Use a 55 to 65-ton shovel with 1½ to 2½-yd. dipper where cuts are heavy, and moves not very frequent. Use a 70 to 90-ton shovel, with 2½ to 3½-yd. dipper on heavy cuts, where moves are infrequent. Of course a heavy shovel with a small dipper is necessary in hardpan and very tough material.

The cost of operating a 55-ton shovel is ordinarily as follows, (at 1914 wages and prices), assuming 22 days worked during the month, and 6 months worked during the year, or 132 days actually worked per year:

	Per day worked
Shovel Crew:	
1 engineman on shovel, at $125 per month	$ 5.70
1 craneman on shovel, at $90 per month	4.10
1 fireman on shovel, at $65 per month	3.00
6 pitmen, at $1.75 per 10-hr. day	10.50
1 night watchman, at $50 per month	2.30
Total shovel crew	$ 25.60
Coal for shovel, 1¼ tons, at $4, delivered	$ 5.00
Water	3.00
Oil and waste	0.50
Interest on $7,200 shovel at 6% per year ÷ 132 days	3.25
* Repairs on $7,200, 3% per month ÷ 22 days	10.00
Depreciation on $7,200, 6% per year ÷ 132 days	3.25
Total steam shovel crew, fuel, repairs, etc.	$ 50.60
Moving and housing shovel once during year, say, $500 ÷ 132 days..	4.00
Total charges on shovel	$ 54.60

* Repairs are less in earth than in rock. In the soft rock on the Panama Canal, monthly repairs averaged 4% of the first cost of shovels, working one 8-hr. shift.

Train Crew:	
2 enginemen (on 2 dinkeys), at $3	$ 6.00
2 trainmen, at $2	4.00
6 dumpmen, at $1.75	10.50
Total train crew	$ 20.50
Coal for 2 dinkeys, 0.6 ton, at $4	$ 2.40
Water	1.50
Oil and waste	0.50
Interest on $8,000 (2 dinkeys and 24 cars), at 6% per year ÷ 132 days	3.65
Repairs on $8,000, at 1½% per month ÷ 22 days	5.45
Depreciation on $8,000, at 8% per year ÷ 132 days	4.85
Total train crew, fuel, repairs, etc.	$ 38.85
Moving and housing locomotives and cars once during year, same as for shovel	4.00
Total charges of locomotives and cars	$ 42.85
Track Crew and Track:	
6 men grading and track shifting, at $1.75	$ 10.50
Interest on $2,250 (rails (35 lb. per yd.) and fastenings for 1 mile track), at 6% ÷ 132 days	1.00
Depreciation on $2,250, at 12% ÷ 132 days	2.00
Interest on $750 (ties, at 30 ct. each, 2 miles track), at 6% ÷ 132 days	0.35
Depreciation on $750 (ties), at 10% per month ÷ 22 days	3.50
Total track crew and track $ 17.35	
Supervision, Etc.:	
½ superintendent, at $150 per month	$ 3.50
1 foreman, at $75 per month	3.50
1 timekeeper, at $65 per month	3.00
General management, office expenses, etc., 6% of daily payroll	4.00
Total supervision, etc.	$ 14.00
Grand total	$128.80

Summarizing we have the following daily cost and cost per cu. yd. when the daily output is 1,000 cu. yd. (or 22,000 cu. yd. per month):

	Per day	Per cu. yd. ct.
Shovel expenses	$ 54.60	5.46
Train expenses	42.85	4.29
Track expenses	17.35	1.73
Supervision, etc.	14.00	1.40
Total	$128.80	12.88

Substitute existing wages and prices for those above given. Wages of construction forces and prices of construction outfits are now (1919) double what they were in 1914.

Tough material and unfavorable conditions frequently reduce the daily output to 600 cu. yd., and run the cost up to 21 ct. per cu. yd.

The most variable of the four main items of daily expense is Track Expense. Often a large crew of men is kept busy grading for new tracks, although it is rare that more than 10 or 12 men are thus engaged for each shovel crew.

The estimated percentages for repairs and depreciation are liberal, but it must be remembered that repairs increase as the machines grow older, and that a high allowance should be made for depreciation to cover obsolescence, i. e., the "getting out of date" or behind the times.

Depreciation of ties is especially rapid in contract work, due to the destruction that occurs from frequent track shifting. Depreciation of rails is also rapid, due to their becoming kinked.

The foregoing itemization of cost should be taken merely to represent a fairly typical example (at prewar wages), but each particular case will have its varying conditions that must be considered.

Where temporary trestles must be built to carry the cars out over proposed fills, as is common on railway work, the cost of the trestles must be added to the above figures. Much lighter timbers can be used for dinkey locomotives and trains than for standard railway tracks. It should also be remembered that round poles can usually be secured for the legs or posts of trestle bents, and that each bent usually has only two legs. The squared stringers, ties and caps can usually be recovered, but the posts, sills and sway braces are buried permanently in the fill.

The cost of trestles is given in detail in Gillette's "Handbook of Cost Data."

Analysis of Costs of Steam Shovel Work. An abstract from "Handbook of Steam Shovel Work," a report by the Construction Service Co., to the Bucyrus Co., which was given in *Engineering and Contracting*, Dec. 13, 1911, follows.

There are so many factors entering into steam shovel work that the problem of determining the cost details seems at first highly complex, but systematic analysis has resulted in so simplifying it that any man of field experience ought to be able, with the help of the following data, to put his shovel work on a scientific basis. To determine what the work is costing day by day, is half the problem: to determine what it ought to cost is the other half.

To establish these factors it was necessary to observe a large number of shovels in operation, and the data given are the results of the observation of nearly 50 different shovels at work in various kinds of earth and rock.

The unit costs of working by hand will be nearly the same, field conditions being equal, whether the job is a large one or comparatively small. The steam shovel is dependent for its work upon so many factors, any one of which may greatly help or hinder it, that there is a far greater diversity of results than in the case of handwork. The question of how much work there

must be to justify the use of a steam shovel is vital in a large percentage of all excavation contracts.

Repairs and Depreciation. Repair costs should be apportioned to the work done rather than considered a function of the age of the shovel. It will be higher for rock than earth, and higher for poorly broken rock than for well blasted material. Time alone doesn't affect the unit cost of repairs.

In the item of *depreciation* the reverse of this proposition obtains. If the machine be kept in proper repair, the depreciation is effected by time alone, regardless of the work the machine is doing. Many concerns class this item and repairs under one account, but this practice is inaccurate and misleading. There is a great disagreement among accountants as to how depreciation should be figured and there are many so-called depreciation formulas and curves. The simplest to use, and one which for steam shovel work is satisfactory if proper allowance is made for repairs, is the "straight-line formula," which is as follows:

$$X = \frac{(a - b)\ c/d}{a}, \text{ where } a = \text{original value,}$$

b = value on removal.
c = time in use.
d = estimated life.
X = % of depreciation.

Then X divided by the output for the period *c* will be the cost of depreciation per unit of performance.

The working life of a shovel may be assumed to be 20 years, and assuming the first cost at \$150 per ton, and its scrap value at \$10 per ton, the value for X with a 10-year-old shovel, would be

$$\frac{(\$150-\$10)}{\$150} \times \frac{10}{20} = 46.67\% \text{ in the 10 years or } 4\tfrac{2}{3}\% \text{ per year.}$$

The *interest* on all money invested in this work must be included in the costs of the work. In this discussion the interest is assumed as 6%.

The *height of bank* to which a shovel can work has an important bearing upon the costs. The reason for this is that the higher the bank the larger amount of material that can be removed without moving the shovel.

Cost Formula. The following analysis of steam shovel work is based on the results of observations of about 50 shovels at work. The wages of the different classes of men were standardized as listed below for purpose of analytical comparison. In connection with this analysis the accompanying curves of cost are useful in enabling a rapid estimate to be made of the approximate cost of steam shovel work in progress or proposed:

d = time in minutes to load 1 cu. ft. with dipper (place measure).
c = capacity of 1 car in cu. ft. (place measure).
f = time shovel is interrupted while spotting 1 car.
e = time shovel is interrupted to change trains.
g = time to move shovel.
L = distance of 1 move of shovel.
N = number of shovel moves.
M = minutes per working day less time for accidental delays.
A or B = area in sq. ft. of section excavated.
R = cost in cents per cu. ft. on cars, for shovel work only (place measure).
L A N = cu. ft. excavated per day.
C = shovel expense in cents in 1 day, not including superintendence and overhead charges and not including preparatory charges.
n = number of cars in train.

(1) Time to load 1 car = dc.

(2) Time to load 1 train = n d c + n f + e.

(3) Number of trains for 1 shovel move $= \dfrac{LA}{nc}$

(4) Time between beginning of 1 shovel move and beginning of next =

$$(ndc + nf + e)\frac{LA}{nc} + g.$$

(5) $$N = \frac{M}{\left(dc + f + \frac{e}{n}\right)\frac{LA}{c} + g}$$

(6) $$R = \frac{27Cd}{M} + \frac{27C}{M}\left(\frac{f}{c} + \frac{e}{nc} + \frac{g}{LA}\right)$$

This is equivalent to the equation R = md + b.

(7) Where $m = \dfrac{27C}{M}$, and

(8) $$b = m\left(\frac{f}{c} + \frac{e}{nc} + \frac{g}{LA}\right)$$

The following standards have been assumed for a shovel valued at, say $14,000:

	Per year
Depreciation, 4⅔%	$ 653.34
Interest, 6%	840.00
Repairs, when working one shift	2,000.00
	$3,493.34

	Per day
Assuming year of 150 working days *	$23.29
Shovel runner	5.00
Craneman	3.60
Fireman	2.40
½ watchman at $50 per month	1.00
6 pitmen at $1.50	9.00
1 team hauling coal, water, etc., ½ day, say, at $5	2.50
2½ tons coal at $3.50	8.75
Oil, waste, etc., say	1.50
Total per day	$57.04

* For various reasons, such as lack of continuous work, weather, etc., 150 working days per year is assumed. This will vary greatly with local conditions.

It appears that the equation $R = md + b$ is that of a straight line. Now, since the equation

$$m = \frac{27C}{M} \text{ and } b = m\left(\frac{f}{c} + \frac{e}{nc} + \frac{g}{LA}\right),$$

all quantities involved in the equation excepting d are, or are assumed to be, constant. The data upon the value of these quantities have been represented in graphic form with all influencing factors by the five figures A, B, C, D, and E.

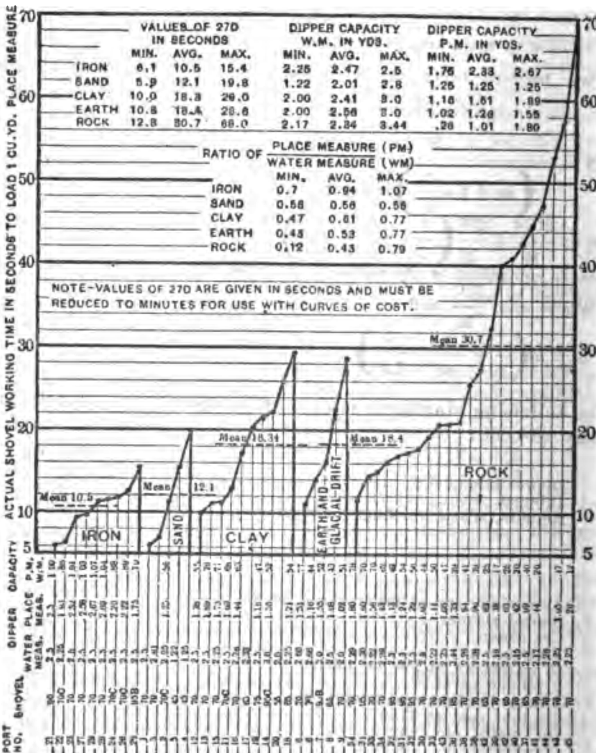


Fig. 18. Diagram for Use with Cost Curves. (Value of 27d Shown Graphically.)

Fig 18 indicates the time to load 1 cu. yd. place measure, in various kinds of material. Fig. 19 deals with the quantities e,

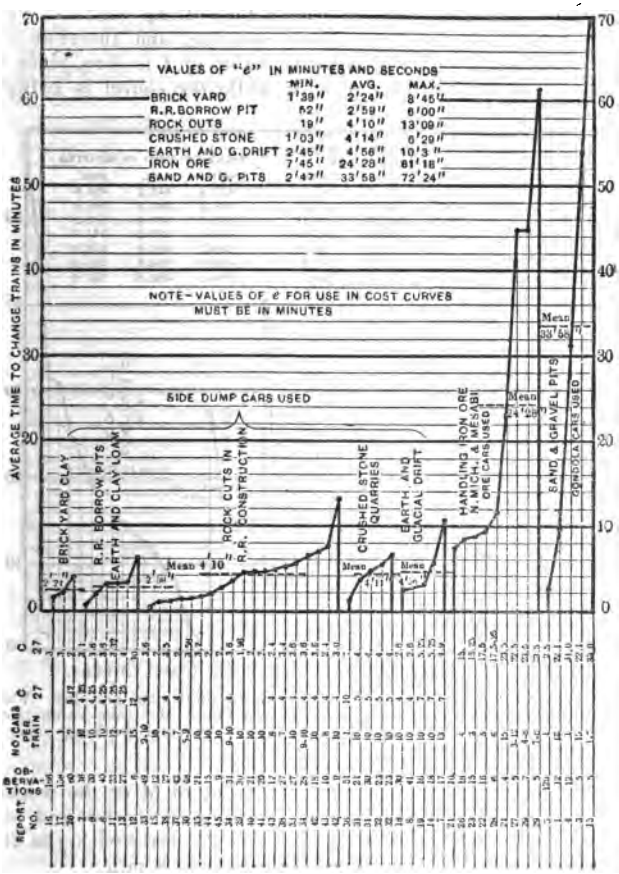
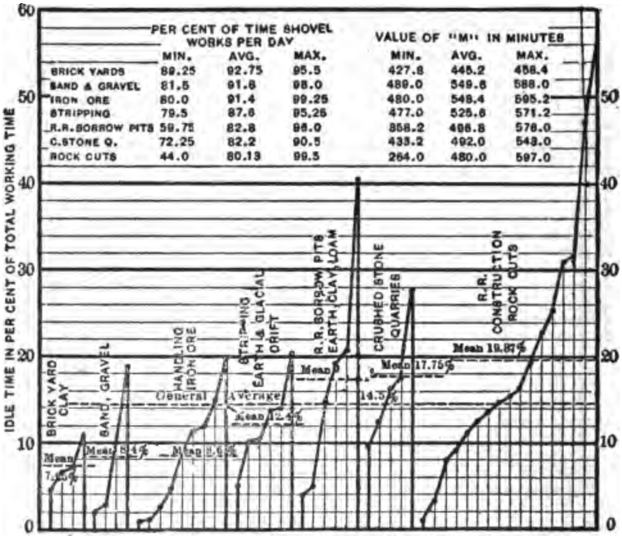


Fig. 19. Diagram for Use with Cost Curves. (Value of e Shown Graphically.)

average time shovel is interrupted to change trains. For use in plotting the equation above, those average values of e, n, c and f involved in ordinary contracting work where side dump

cars are used, have been tabulated separately in Fig. 19. It will there be seen that the average value for e, the time between trains is 4 min. The average number of cars per train, or n = 10. The commonest form of contractors' dump car is 4 yards water measure or 2.5 yards place measure, and therefore c is taken as 67.5 cu. ft. The ordinary value of f is zero, since the cars are almost invariably spotted while the shovel is swinging



	PER CENT OF TIME SHOVEL WORKS PER DAY			VALUE OF "M" IN MINUTES		
	MIN.	AVG.	MAX.	MIN.	AVG.	MAX.
BRICK YARDS	89.25	92.75	95.5	427.8	445.2	458.4
SAND & GRAVEL	81.5	91.6	98.0	489.0	549.6	588.0
IRON ORE	80.0	91.4	99.25	480.0	548.4	595.2
STRIPPING	79.5	87.6	95.25	477.0	525.6	571.2
R.R. BORROW PITS	59.75	82.8	96.0	358.2	496.8	576.0
C. STONE Q.	72.25	82.2	90.5	433.2	492.0	543.0
ROCK CUTS	44.0	80.13	99.5	264.0	480.0	597.0

Fig. 20. Diagram for Use with Cost Curves.

(Idle time shown graphically in per cent. of total time per day. Values of "M" to be taken from this diagram. To find "M" take value plotted below subtract from 100% and multiply result by total working time per day, generally 10 hours.)

and digging. Fig. 20 deals with the value of M or the working time, including actual shovel time waiting for trains and moving up, but not accidental delays. Fig. 21 deals with the time of moving up, an average value for which is 8 min.

The constants having thus been established, three sets of curves have been plotted on Figs. 22, 23, 24 which are cost curves. Each plate is plotted with one of the three values of L A 1,500, 3,000 and 6,000 cu. ft. (L being the average shovel move, 6 ft., and A the area of the dug section in sq. ft.). Each of these sets of curves has been plotted for values of M, ranging from

2 hr. to 10 hr. by hourly intervals between which intervals the observed values (see Fig. 20) fall.

Estimating. There are two important uses to which these cost curves can conveniently be put, (1) estimating the cost of proposed work and (2) checking up the cost of work under way. In estimating we may proceed as follows: Assuming that the proposed work is to be a railroad cut in rock, with average equipment, there are then only three quantities to decide upon, namely, LA, 27d, and M. The area of the shovel section being assumed at 250 sq. ft. and the average distance of move being 6 ft., LA

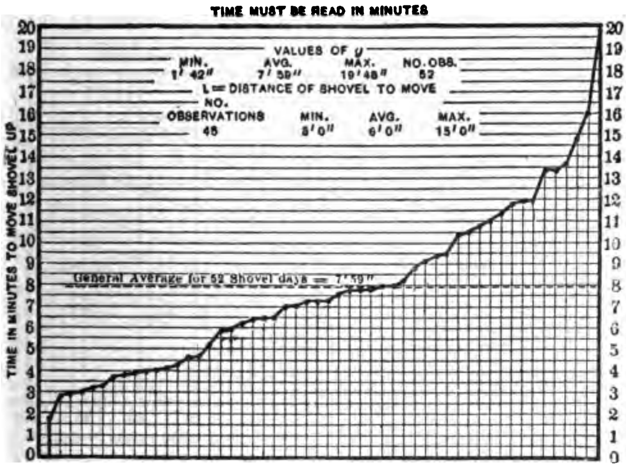


Fig. 21. Diagram for Use with Cost curves. (Value of g Shown Graphically. Read Time in Minutes.)

will equal 1,500 cu. ft. Now refer to Fig. 18, and select a fair value for the time of loading 1 cu. yd. in rock work. Suppose 30 sec. be chosen. Next refer to Fig. 20 for the proper value of M to use in rock work. The average value is 8 hr. (80% of 10 hr.). The cost per yard in cents can now be read directly on cost curves, Fig. 23. With abscissa (27d) as 30 sec. glance upward till the vertical line through 30 sec. intersects the 8 hr. M line. Then on the left, opposite this point of intersection read 9½ ct. as the cost per cu. yd. loaded, place measure.

It may be noted here that with respect to the two important items of time to load 1 cu. yd. with dipper and values of M, the cost curves are perfectly flexible. Variation in the value of

the constants may be allowed for by proper choice of M. In connection with the formula it is interesting to note the effect of decreasing the carrying capacity of each train, other conditions remaining the same. Suppose the carrying capacity be decreased from the average 10 × 2.5 yd. = 25 cu. yd. to 8 × 2 = 16 cu. yd., place measure, what would be the effect upon the cost per cu. yd.? The new cost would be 10.6 ct. per cu. yd. as against the former 9.5 ct., an increase of 10%.

To use the cost curves for checking up the cost of work in progress, proceed as follows: The field operations are few and simple. Find the average time per dipper swing. Knowing the rated capacity of the dipper and the character of the ma-

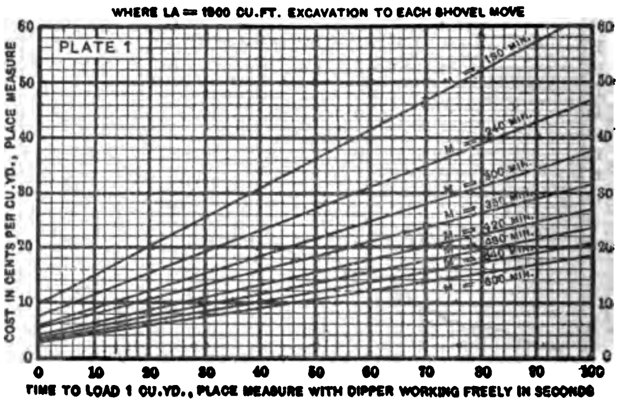


Fig. 22. Cost Curve.

terial, a glance at the tabulation near the top of Fig. 18 will give the ratio of dipper capacity place measure to dipper capacity water measure, and by using this factor the average factor of dipper (place measure) can be obtained, and thence the time to load 1 cu. ft. or yd. Suppose, for instance, the average time per swing to be 25 sec., in earth material, and the capacity of dipper, 2¼ yd. On Fig. 18, under ratio of place measure: water measure, we find the average value is given as 0.53. Therefore, 2¼ × 0.53 = 1.2 cu. yd. per swing or 2.88 cu. yd. per min. or 0.35 min. per cu. yd. Make some rough measurements to determine the approximate area of the shovel section and multiply this area by the length of move, and get LA, say 3,000. Then, from previous observations or by an estimate of M, get the time worked per day, less accidental delays, say 9 hr. Now take the

cost curves, Figs. 22 to 24, and with .21 as abscissa, read opposite the line, for $M = 9$ hr., 6 ct. as the cost per yd. place measure. If the contents in the formula do not agree closely enough with the actual conditions, allow for this by choosing a suitable value of M, or substitute directly in the equation for cost.

Formula $R = \frac{27Cd}{M} + \frac{27C}{M}\left(\frac{f}{c} + \frac{e}{nc} + \frac{g}{LA}\right)$

Assume —

$f = o$, interruption of shovel while spotting cars.
$e = 4$ min. time between trains.
$n = 10$, number of cars per train.
$c = 2.5$ yd. place measure $= 6.7$ cu. ft.
$C = 5,704$ ct., daily cost.
$M =$ actual working time of shovel.
$g = 8$ minutes, see Fig. 4.
$d =$ Minutes to load 1 cu. ft. place measure.

It should be noted that the above does not include superintendence or overhead charges and covers only the cost of loading. It should be particularly noted that for plotting the two coordinates, certain assumptions are necessary because there are a large number of variables in the theoretical steam shovel formula.

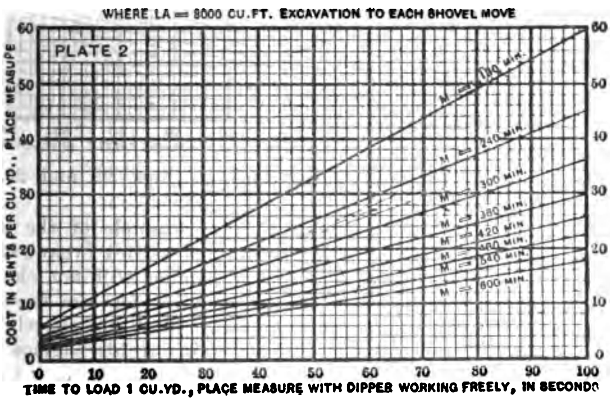


Fig. 23. Cost Curves. (From Daily Cost "C." Itemized in Text.)

Thus, the three diagrams are given — one for $LA = 1,500$, one when LA is 3,000 and one where it is 6,000. Also an assumption of \$57.04 for the value of C is made. Where the shovel differs very much in type from the one mentioned, or where the rates of wages are very different from those assumed, it will be neces-

sary to compensate for the difference between the new value of C, and the one used here. The easiest way to do this is to multiply the figures taken from the diagram by the ratio between the new value of C and the assumed one. Thus, if the shovel costs per day are $65 instead of $57.04, and the diagram should give a cost for loading of 12 ct., we would have for our charge 12 ct. multiplied by $65 and divided by $47.04 or 13.67 ct. per yd.

The quality and amount of superintendence will greatly affect the unit costs of the work; and by superintendence is meant, not only the man in charge, but his whole directing organization.

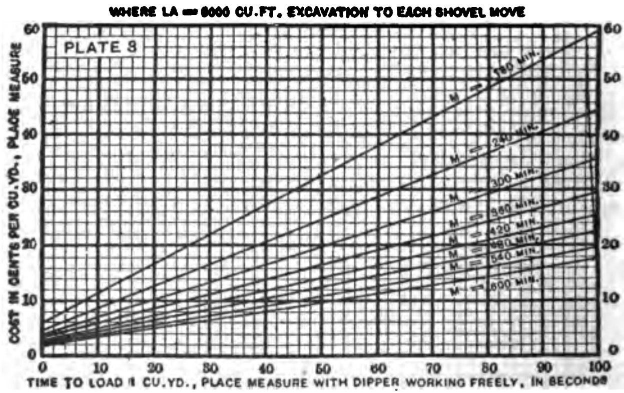


Fig. 24. Cost Curve. (Value Same as Figs. 22 and 23.)

The work in the iron ore country is an example of the work which may be accomplished in the way of skilled organization. Pure observation alone without actual timing will not show a superintendent whether it is more economical for him to use 9 or 10 car trains to haul material away from his shovel. He will generally favor the use of long trains if his engines will haul them. Yet money has been saved by shortening trains even when the engines could easily haul the longer ones. In this case the key to the situation was the time required to dump and transport.

Values of *e*, *n*, *c*, *f*, involved in ordinary contracting work with side dump cars.

e = Average time shovel is interrupted to change trains.
n = Number of cars per train.
c = Capacity of cars in cu. ft. (place measure).
f = Time to spot one car.
c' = Capacity of cars in cu. ft. (water measure).

	Values of n			Values of c				
	Min.	Avg.	Max.	Min.	Avg.	Max.	f	c'
Brick yard clay	1	1–2	2	54	72	81	Zero	...
R. R. borrow pits	7	11	15	83.7	126	270		151
Rock cuts	7	9	12	54	75	97.2		188
Crushed stone quarries	1	10	10	108	124	189		162
Earth and glacial drift.	10	10–11	13	70	108	141		157
Iron ore (Minn.)	3	7	12	270	540	675		540
Sand and gravel pit ...	1	7	15	67.5	598	891		...

General average of e, n, c, f, c', as follows

	No. of Obs.	Minimum	Average	Maximum
e	35	.25 min.	4.00 min.	13.5 min.
n	35	5.0 cars	10.00 cars	15.0 cars
f	0	0	0	0
c	35	2 yd.	4.00 yd.	10.00 yd.
c'	27	4 yd.	5.00 yd.	12.00 yd.
c/c'	27	0.5	0.8	0.95

Repairs of Steam Shovels, Cars and Locomotives on the Panama Canal. The following is an abstract of the "Annual Report of the Isthmian Canal Commission" printed in *Engineering and Contracting*, Dec. 22, 1909:

According to the last annual report of the Isthmian Canal Commission, the following were the principal items of equipment used in excavating and transporting earth and rock, on June 30, 1909:

TABLE FOR USE WITH COST CURVES

Steam Shovels:	
1 (20-ton) shovel, 1¼-yd. dipper	$ 5,788
10 (45-ton) shovels, 1¾-yd. dipper, at $7,100	71,000
42 (70-ton) shovels, 2½-yd. dipper, at $9,381	494,002
47 (95-ton) shovels, 5-yd. dipper, at $12,760	599,720
100 total steam shovels, at $11,705	$1,170,510
Locomotives:	
119 French locomotives, at $4,250	$ 505,750
164 American locomotives, at $11,600	1,902,400
283 Total locomotives, at 8,509	$2,408,150
Cars:	
621 French dump cars at $225	$ 139,725
1,324 American dump cars at $1,400	1,853,600
1,765 wooden flat cars at $1,050	1,853,250
500 steel flat cars at $861	430,500
35 narrow gauge cars at $227	7,945
4,245 Total cars at $1,010	$4,285,020
Unloaders, etc.:	
30 Lidgerwood unloaders at $5,000	$ 150,000
46 unloading plows at $950	43,700
24 bank spreaders at $5,200	124,800
10 track shifters at $4.050	40,500
16 pile drivers at $3,700	59,200
Total unloaders, etc.	$ 418,200
Grand total	$8,281,880

The 100 steam shovels averaged a 78-ton weight, and a first cost of $140 per ton; and daily repair cost of about $25.

The prices paid for this plant include the cost of delivery at Colon.

The cost of shop repairs made by the mechanical division during the year on the different units of equipment enumerated in the above table, including direct and overhead charges, was as follows:

	Each per annum
283 locomotives (93 repairs on each)	$1,226
4,210 freight cars (29½ repairs on each)	150
119 work cars (7 repairs on each)	338
100 steam shovels (shop repairs only)	1.976

The total shop repairs on these locomotives, cars and steam shovels amounted to $1,217,058 for the year, not including field repairs on the steam shovels. While the report does not give field repairs, we have included here some data taken from the *Canal Record* and published in our issue of Oct. 20, 1909. The shop cost does not include the cost of repairs made in the field or that of repairs made to steam shovel parts taken to the shops while the shovel is kept in service by substituting other parts. These repairs are known as field repairs and are made in the field shops and on the work, often while the shovel is waiting for cars. The cost of steam shovel repairs in the three construction divisions from January, 1908, to June, 1909, inclusive, a period of 18 months, was 3.03 ct. per cu. yd. for 33,882,000 cu. yd.

	Divisions			
Item	Central	Atlantic	Pacific	Total
Cubic yards	27,752,750	4,148,997	1,980,069	33,881,816
Field cost	$596,059,02	$51,786,74	$19,917.58	$667,763.34
Shop cost	$283,746.76	$51,782.61	$22,246.75	$357.776.12
Cost per cu. yd.	Ct.	Ct.	Ct.	Ct.
Field	2.14	1.25	1.01	1.97
Shop	1.02	1.25	1.12	1.06
Total	3.16	2.50	2.13	3,03

The shovels in the Central Division are subjected to harder and more constant usage than those of the other two divisions. Of the 101 steam shovels in the Canal and Panama railroad service 61 are in the service of the Central Division, most of them in Culebra Cut.

The repairs on locomotives and cars include field repairs as well as shop repairs. It will be noted that locomotive repairs amounted to 14½% of the first cost of the locomotives. This is about the percentage it costs to maintain railway locomotives

in America, exclusive of entire renewals of worn out equipment, but the report does not give the weights of locomotives, so it can not be determined whether the price of the French locomotives is a second-hand price or not. As the locomotives grow older, the cost of repairs will increase, unless the efficiency of the men engaged in repair work increases.

The total cost of repairing cars was about 15% of the first cost.

The shop cost of repairing steam shovels was 17% of the first cost. The average shovel has been put into the shop for general repairs once in 24 months, and that $3,800 was spent on each shovel during such period of general repairs. As above shown, the field repairs averaged twice as much as the shop repairs; hence the combined annual field and shop repairs totaled 50% of the first cost of the shovels.

For total "maintenance and repairs," the mechanical department expended the following sum during the year:

Materials	$ 595,050
Labor	1,245,448
Total	$1,840,498

This is $623,000 more than the total cost spent on the steam shovels, locomotives and cars, and probably covers repairs to all other parts of the plant, including rock drills, etc.

Expenditures of the mechanical department for work done for "other departments" was $1,504,315, but this is not itemized.

The monthly payroll of the mechanical department was $159,-934, for 2,125 employees. The following rates of wages were paid, and the percentage by which their wages exceed those paid in the U. S. navy yards:

	Wage, 8 hr.	Per cent. increase
Blacksmith —		
59 general	$4.74	31
5 machine	5.25	37
3 brick layers or masons	5.76	19
138 boiler makers (general)	4.86	41
180 carpenters (house)	5.36	52
34 molders (loam)	5.47	51
26 painters (house)	5.06	55
6 pattern makers	6.18	52
33 pipe fitters	5.15	44
33 plumbers (house)	5.92	55
2 tinsmiths	5.52	62
7 coppersmiths	5.33	42
5 engineers (steam)	4.77	40
Machinists —		
269 general	4.91	37
58 floor hands	5.10	43
38 tool hands	4.82	33
33 wire men (electric)	4.93	46
929 total.		

"So far as hourly rates of pay for 'gold' employees are concerned, the first-class pay remains almost uniformly 65 ct. an hour ($5.20 for 8 hr.)."

The following data are taken from the Panama Canal special issue (66 pages) of *Engineering and Contracting*, Jan. 7, 1914.

Five sizes of shovels were employed as follows:

Name —	Dipper capacity
45-ton Bucyrus	1¾ cu. yd.
70-ton Bucyrus	2½ cu. yd.
95-ton Bucyrus	5 cu. yd.
No. 60 Marion	2½ cu. yd.
No. 91 Marion	5 cu. yd.

The number of each type used each year varied; the number of all shovels used each year and the average output of all shovels are given in Table I.

These performance records and all others which will be stated are based on an 8-hr. working day. The best performances per day, month and year of steam shovels of the sizes named above for the five years are given in Table II.

Maintenance of Shovels. Steam shovels were maintained by shop and field repairs. Priod to Oct. 1, 1909, all shop repairs of steam shovels were made at the Empire shops and were in charge of the Mechanical Division and all field repairs were made by the construction division. On the date named the Empire Shops were removed from the direction of the Mechanical Division and transferred to the Central Division, and were made virtually steam shovel repair shops for the whole canal.

A field repair system was begun Nov. 5, 1907, and it comprised a force of boiler workers, pipefitters, machinists and helpers who made all repairs at night after the shovels were shut down. The force was divided into three gangs, each covering a certain section of the excavation. A machine shop car, equipped with a forge, drill and shaper and carrying necessary small tools, and a locomotive crane constituted the field repair plant. The field repairs included replacing and repairing circles, booms, dippers and dipper sticks. A-frames, hoisting drums, main and propeller shafts, swinging drums, intermediate shafts, water tanks, feed pumps and trucks and in one or two cases even renewal of boilers. In fact it was seldom that a shovel was sent to the shops for repairs short of complete overhauling. The numbers of shovels repaired per night by the field repair gangs run from 14 to 20.

TABLE I

Year —	1907–08	1908–09	1909–10	1910–11	1911–12
Shovels worked	59	75	61	52	46
Number working days	305	304	304	304	304
Cu. yd. per day	932	1,199	1,231	1,314	1,319
Cu. yd. per month	23,685	30,371	31,185	32,635	33,038
Cu. yd. per hr. at work	199	225	236	241	246
Cu. yd. per hr. under steam	121	150	156	166	165

TABLE II

Item —	45-ton Bucyrus	70-ton Bucyrus	95-ton Bucyrus	No. 60 Marion	No. 91 Marion
High daily, date	Feb. 5, '08	Mar. 19, '12	Mar. 22, '10	Apr. 18, '08	June 21, '09
High daily, yardage	1,356	2,900	4,465	1,904	3,485
High monthly, month	July, '08	Mar., '09	Mar., '10	Mar., '08	Aug., '08
High monthly, yardage	25,713	53,043	70,290	41,219	55,419
High monthly, days worked	26	27	26	26	25
High annual yardage	105,740	300,872	543,481	......	441,927
High annual days worked	131	254	295	......	299

The cost of shop and field repairs per steam shovel per service day from June 1, 1910, to July 1, 1912, was as follows:

Six months to July 1, 1910	$27.66
July 1, 1910, to July 1, 1911	22.21
July 1, 1911, to July 1, 1912	22.95

The cost of excavating the soft rock of the Culebra Cut was as follows in 1911 and 1912:

	1911	1912
Clearing	......	$0.0001
Drilling	$0.0503	.0535
Blasting	.0547	.0622
Loading	.0493	.0492
Tracks	.1014	.0885
Transportation	.0816	.0734
Dumps	.0488	.0423
Pumps	.0038	.0041
Maintenance of equipment	.0875	.0243
Plant, arbitrary	.1000	.0394
Division expenses	.0128	.0145
Administration	.0462	.0364
Total	$0.6364	$0.5479

Prices of Standard Railroad Shovels. The following is taken from R. T. Dana's "Handbook of Construction Plant." About the most powerful steam shovel built for ordinary grading weighs 95 tons, and for general work a 5-yd. dipper may be used, but for iron ore or shale an extra heavy one of 2½ or 3½-yd. capacity is better. The clear lift from the rail to the bottom of the open dipper door is 16 ft. 6 in. and the maximum width of cut 8 ft. above the rail is 60 ft. This 95-ton shovel has a record output of four to five thousand yards per day.

A steam shovel adapted to extra hard condidtions is the 80-ton; the bucket used is generally 3 cu. yd. for rock work or 4 yd. for earth. The clear lift is 16 ft. and the width of cut 60 ft.

A 70-ton shovel is the one most in demand for heavy work under average conditions. It carries a 2 to 3½-yd. dipper; the clear lift is 16 ft. 6 in.; width of cut, 60 ft.

For work where the depth or amount of excavation is not great enough to warrant a 70-ton shovel a 60-ton is more economical. A 2½-cu. yd. dipper is generally used; clear lift, 15 ft.; width, 54 ft.

A 45-ton shovel is designed for use on fairly heavy work, but where lightness and ease of transportation are essential. Capacity of dipper, 2 yd.; clear lift, 14 ft.; width of cut, 50 ft. A 40-ton shovel is designed for lighter work or sewer excavation.

The prewar price of steam shovels was as follows:

Weight	1914 Price
120 tons	$14,500
95 tons	12,700
85 tons	11,250
70 tons	9,250
60 tons	8,500
45 tons	7,000
40 tons	6,500

Shovels fitted with electric motors cost from $1,000 to $2,500 more than steam-driven shovels.

[The prices in June, 1919, were about 2.5 times those of 1914, both for steam shovels and dinkeys. Dump cars doubled in price during the war.]

From observations made on 50 steam shovels in actual operation during a considerable number of weeks the average number of cubic yards per day excavated by all shovels in all materials was 934. This is perhaps less than may be expected on a well-managed job. A shovel should load a dipper 60% full every

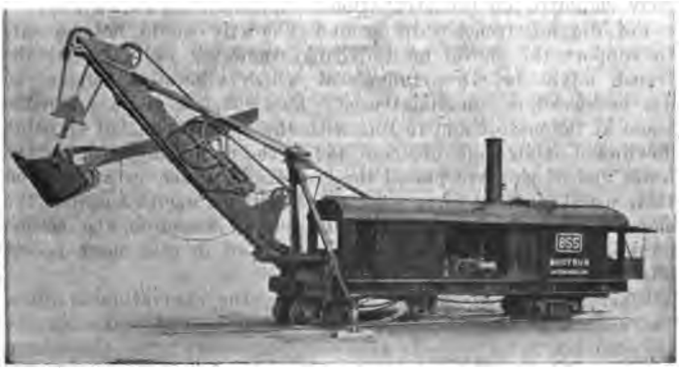


Fig. 25. 95C Bucyrus Steam Shovel.

20 sec. while actually working. About 50% of the time the shovel is held up by various causes, such as waiting for trains, moving ahead, waiting for blasts, and making repairs. With a 2½-yd. dipper a shovel should, therefore, excavate 1,350 cu. yd. in 10 hr.

The maximum width of cut given by shovel manufacturers is far greater than the actual average as recorded in observations made by the author. 70 to 95-ton shovels make an average cut of 28½ ft. wide. With a 30 or 40-ton shovel the average cut is not much more than 20 ft. in width.

45, 60 and 70-ton shovels equipped with dipper handles 45 to 55 ft. long are used for excavating large trenches. A 70-ton shovel was employed in excavating a sewer trench 16 ft. wide by 26 ft. deep in Chicago in 1909. This shovel was of the latest design, equipped with a 54-ft. dipper handle and a 2-yd. dipper, with the operating levers placed far forward so as to enable the runner to see the bottom of the trench. The shovel had been removed from its trucks and mounted on a footing, 24 ft. wide by 38 ft. long, of heavy wood beams trussed with steel rods. This platform rested on rollers, which in turn rested on running planks laid on the trench bank. To move the shovel a cable was attached to a dead man and wound up by the shovel engine. The average length of forward move was 15 ft. The shovel moved back 416 ft. in 3½ hr. 569 cu. yd. were loaded in a day into 4 and 6-yd. narrow gauge cars drawn by 18-ton dinkeys. The crew consisted of 1 engineman, 1 craneman, 1 fireman, and 7 roller men. In addition 6 trimmers, 6 bracers, and 1 foreman were employed on the excavation.

For digging trenches in ground where it would not be safe to support the shovel on the banks, however well sheeted the trench might be, an arrangement which allows the shovel to dig backward is sometimes used. This consists of an extension boom at the end of and in line with the main boom, but slanting downward at an angle of about 45° to the perpendicular. On the lower end of this are placed the crowding engines, reversed from their usual position, thus pointing the dipper mouth towards the shovel. This allows the shovel to remain ahead of the trench on solid ground. A 46-ton shovel equipped in this manner cost $9,000 in 1909.

Where a through cut is being made, the excavation is often too narrow to permit the shovel to turn around and excavate the next cut in an opposite direction, but necessitating the return of the machine backward to the starting point for the next cut. Sometimes this return is 3 or 4 miles long and costs considerable in lost time as well as money. In such a situation the shovel should be equipped with a ball socket, which allows it to be jacked up and revolved on the forward trucks while being held in equilibrium by the weight of the extended bucket and dipper. This equipment costs about $500 extra.

Steam Shovel Dippers. Old style dippers were made of plates and forgings. Modern dippers have special steel front castings and cast steel backs. Solid forged steel teeth are generally used, although teeth of manganese and other special steels are sometimes used. In trench work teeth are often provided at the sides of the dipper as well as in front in order to cut a

straight vertical bank. The author has found it well to point the outside front teeth outward in some soils. In most work the hoisting line is fastened to the dipper bail, but in trench work the bail is sometimes omitted and the hoisting line is connected to the back of the dipper. For soft material the teeth are replaced by a lip or cutting edge.

A Manganese Steel Dipper. *Engineering and Contracting*, July 17, 1912, gives the following:

Three new steam shovel dippers known as the "Missabe" were put in service at Panama. Every part of the dipper, including the back, is of cast manganese steel. This insures durability and a minimum cost in repairs, owing to the toughness and wearing quality of this metal.

The dipper body is composed of only two castings — the front and back halves, this giving great rigidity and eliminating the working and straining of the parts which, in the dipper built up of plates, tends to cause loosening of rivets. The bail brackets are set at an angle conforming to the line of pull on the bail, and by putting them against projecting shoulders cast on the sides of the front casting the shearing strain is relieved from the bail bracket rivets.

Another feature is the placing of the joint, between the front and back casting, *behind* the bail bracket so that the digging strain does not tend to pull the dipper apart. The teeth are riveted on as usual, but are held unusually rigid by means of notches in the lip and shelf or offset on the outside of the lip, upon which rests that portion of the tooth which is on the outside of the lip.

When extra protection for the front of the dipper is desired, a renewable bottom band as well as runners or shoes can be furnished when desired, or they may be cast integrally with the dipper front. All pin holes in bails, hinge brackets and dipper stick brackets are provided with renewable bushings.

This dipper is built in all sizes for the various makes of steam shovels and dipper dredges, and is claimed by the manufacturers to have a life of three or four times that of the built-up type. It is manufactured by the Edgar Allen American Manganese Steel Co., Chicago, Ill.

Designs of Dipper Trips. *Engineering and Contracting*, Nov. 29, 1911, gives the following:

When the shovels arrived on the Isthmus of Panama they were equipped with a single lever latch operated by a $1\frac{1}{4}$-in. rope in the hand of the craneman, and attached at its other end to the "trip" of the dipper. Several pulls were often necessary to open the latch, and almost invariably a great effort was

required. The string by which this "trip" was operated passed through a sheave on the dipper stick near the dipper and thence to the craneman's hand.

The first improvement was to compound this original "trip," and in the drawing herewith, Fig. 26, the compound "trip" is shown. The original was the simple level with the fulcrum at *a*, the weight at *b* and the power at *c*. In the compound "trip," another fulcrum was made at *d* and the power was applied at *e*, where the line was attached. By this device a movement of 20 in. in the line resulted in a 1-in. movement of the latch.

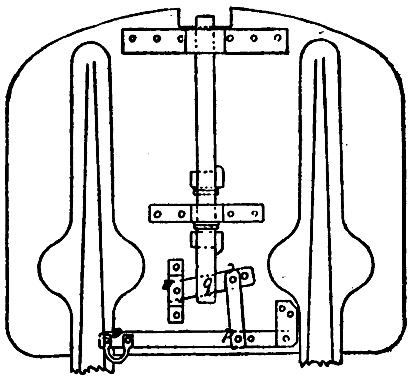


Fig. 26. Door of Dipper of 95-Ton Shovel Showing Compound Latch Trip.

Among improvements upon the compound device, one that was given a trial in 1909 was the "spring trip" which consisted of the lever shown by Fig. 27 and a bar passing through a slot in the latch, with a spring attached at its outer end, the power for unlatching being supplied by the spring. The rope by which the "trip" is operated is attached at *b*; the fulcrums are at *c* and *d*; at *a* is a toggle joint; at *e* the weight; at *f* the power applied by the spring. The door is closed by its own weight, when in digging position, placing a tension of 1,300 lb. upon the spring, and drawing the toggle joint erect. When the dipper is in dumping position, the craneman pulls the rope, thereby breaking the toggle joint and allowing the spring to exert its pull upon the latch, which flies back, permitting the dipper to empty. The spring required was of ½-in. wire, 31 coils, 2¼-in. outside diameter, and 21 in. long when free. This device worked satisfac-

torily, but the toggle joint required constant renewing, and some difficulty was experienced in obtaining suitable spring, so that the appliance was finally abandoned.

The first steam power trip was a device placed upon his shovel by Thomas Custy, a steamshovel engineer, in 1908, but after a few months' trial this was discarded. This device was improved upon by A. H. Geddes, also a steamshovel engineer, until it became practicable, and a patent has been granted to him. It was described at length in *Engineering and Contracting*, issue of May 31, 1911. In this device a steam cylinder is located on the dipper stick near the dipper, the piston is connected with the dipper latch through a chain and a series of levers, and when

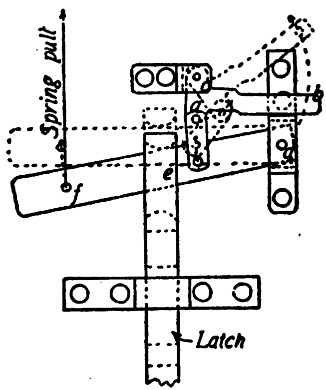


Fig. 27. Portion of Steam Shovel Dipper Door Showing Arrangement of Spring Latch.

steam is admitted to the cylinder the thrust of the piston operates the levers and unlatches the door. Steam is admitted and exhausted from the cylinder through a three-way valve located on the boom beside the craneman's seat. A steam pipe extends from the valve along the boom opposite the dipper stick slot, and at the end of this pipe, and on the cylinder, are universal joints which are connected with one another by a flexible hose. After a thorough trial this device was adopted, upon the recommendation of a committee of two mechanical experts and a steamshovel engineer, who reported that the capacity of a shovel was increased 100 cu. yd. a day by its use.

The latest device, that shown in the illustration, was invented by F. S. Wichman of the Mechanical Division. The latch

is opened by a pull that is made on a ½-in. wire rope by the outward thrust of the piston of an air-brake cylinder. The mechanism is fixed upon the boom of the shovel. A drum is mounted upon the face of the thrusting gear, or shipper shaft, which revolves with the shaft, thus winding or unwinding the tripper rope, according as the dipper shaft moves up or down. In this way the rope is kept taut at all times. To give the lengthwise pull of the cable, a 6-in. diameter steam cylinder is mounted below the drum. This cylinder has a push piston, the outer end of which is bifurcated to receive a sheave, over which

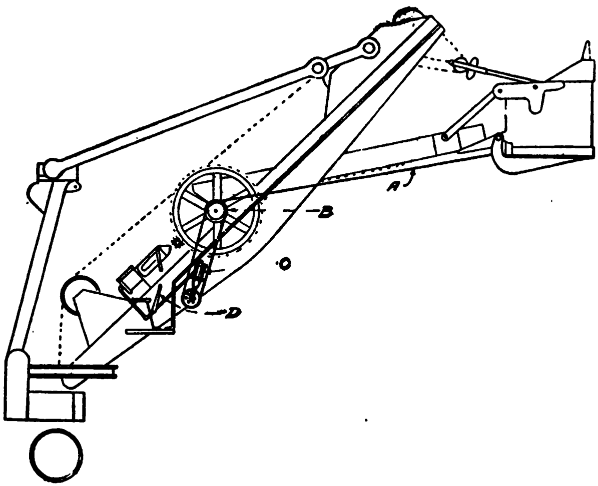


Fig. 28. Steam Shovel Boom Showing Dipper Stick, Dipper and Operating Gear with Wichman Tripping Device.

the cable passes on its way to the drum. Steam is admitted to the cylinder, when it is desired to trip the dipper door, through a three-way cock, operated by a lever at the craneman's seat. When the steam exhausts, the spring in the cylinder pulls the piston back into position, and the tripping operation may then be repeated. This device has undergone a successful test on two 95-ton steamshovels.

The dippers trip selected as the best by the above described tests has been put on the market by the Lines Flyn Co., of New York City.

A Rail Clamp for Steam Shovels and Cars. The following ap-

peared in *Engineering and Contracting*, July 1, 1914. An adjustable rail clamp which will fit any rail from 60 to 100 lb. is made in two styles for 33-in. and 28-in. wheels. It clamps the

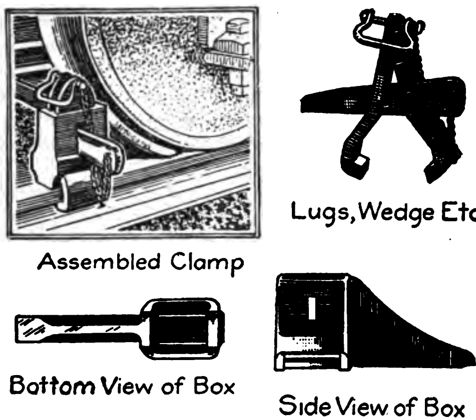


Fig. 29. Adjustable Rail Clamp for Steam Shovel and Cars.

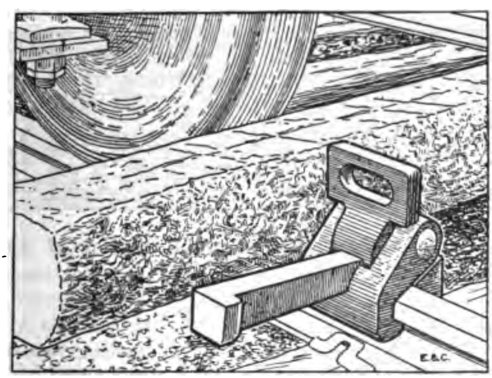


Fig. 30. Bates Rail Clamp for Steam Shovels.

head of the rail and so can be attached anywhere regardless of tie spacing. The bottom bar of the box holds the jaws spread when the clamp is being placed on or lifted from the rail; a

hammer blow loosens or tightens the wedge (Fig. 29). All parts are made of cast steel. The price of the clamp is $15. It is made by the M. & M. Rail Clamp Co., Pittsburgh, Pa.

Another steam shovel rail clamp works like a pair of ice tongs. It grips the ball of the rail and the wedge is driven across the top of the rail; it can therefore be placed anywhere on the rail, even directly over a cross-tie, as in Fig. 30. There are only two parts, the wedge of hardened steel and the tongs which are steel castings hinged by a heavy pin. These clamps are made in three sizes (for 50–60-lb., 70–80-lb., and 90–100-lb. rails) by the Bucyrus Co., South Milwaukee, Wis.

A Flexible Rail Joint. *Engineering and Contracting*, March 18, 1914, gives the following:

The construction and operation of the Thull joint for steam

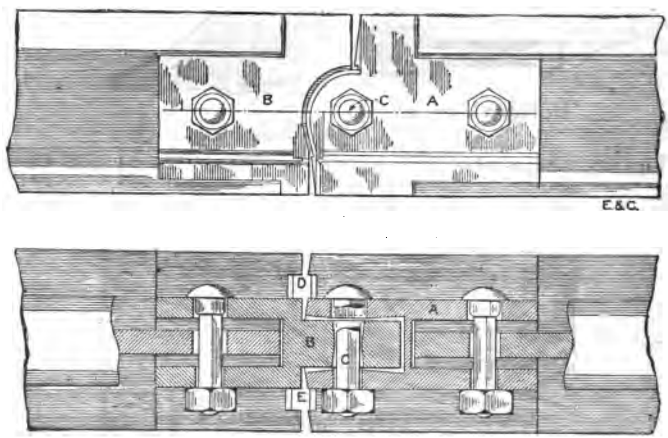


Fig. 31. Side Elevation and Horizontal Section of Thull Rail Joint.

shovel tracks are indicated in Fig. 31. It consists of a male casting *A* and a female casting *B*. These castings are bolted to the rail ends and are hinged by a bolt *C* as shown by the drawings. The hinge *C* provides for joint rotations in the vertical plane; lateral flexibility is provided by the beveling of the socket and other parts by which the two castings engage. A track spike dropped into each of the notches *D* and *E* prevents lateral movement while allowing vertical rotations. The other structural

details are plain from the drawings. This joint has been patented.

A Device for Lifting Jack Blocks. *Engineering and Contracting*, Dec. 11, 1912, gives the following:

A simple device for lifting jack blocks so that they are pulled ahead by the steam shovel itself as it is advanced for a new cut as illustrated in Fig. 32. This device has been used for some time at Lockport, Ill., where the Lincoln Park Commission of Chicago has a shovel and plant for excavating and loading black soil for park surfacing, and it is the invention of Mr. George T. Dows, the superintendent in charge of the shovel and plant. We are indebted to Mr. Dows for sketches and an explanation of the device.

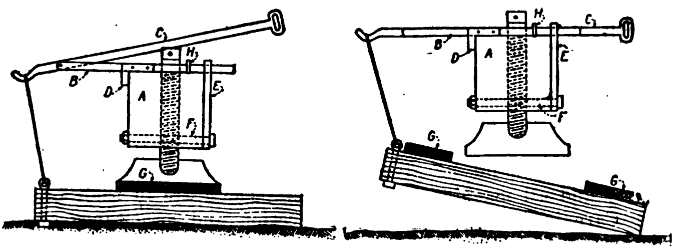


Fig. 32. Device for Lifting and Moving Steam Shovel Jack Blocks.

Referring to the sketches: *A* indicates the end of a Vulcan shovel jack arm with jack screw, shoe and blocking in working position; *B* is a ⅝ x 2-in. steel bar 4 ft. long called a fulcrum bar and *C* is a ⅝ x 2-in. bar 6 ft. long called the lever bar. The fulcrum bar rests across the top of the pick arm when it is held in position by the "lug" *D* and the "latch" *E*. The "latch" has a hook at its top and an eye at its bottom. In the Vulcan jack arm, for which the device was designed, the bolt *F* passes through the eye of the "latch"; in other makes of jack arms which do not have bolts, some other fastening must be devised. The lever bar is hinged to the fulcrum bar as indicated by the sketch; it has a hook at one end and an eye or hand hole at the opposite end. A small rope hangs from the hook end and is attached to an eye bolt set through the jack block. The first sketch shows the position of the jack and blocking when the shovel is working. When about to move the shovel ahead the jack screw is loosened and the blocking *G* is slid from under the shoe. The lever bar *C* is depressed and locked to the

fulcrum bar by means of the hook *H*. This raises the jack block to the position shown by the second sketch and in this position it is easily dragged ahead by the shovel as it moves up to the new cut. A series of operations in reverse to those just outlined adjusts the blocking and jack for the new working position.

Specifications for Steam Shovel Construction. *Engineering and Contracting*, May 1, 1909, prints an abstract of a report by the Committee on Roadway of the American Railway Engineering and Maintenance of Way Association:

One of the tasks allotted to this committee was to submit general specifications for a modern steam shovel for roadway construction and blanks to show the results of steam shovel work, including quantity of material moved and itemized cost of removal. The committee sought the opinion of the association's members by means of a circular letter of inquiry and bases its recommendations on the replies received. The questions, the answers received to them and the decision of the committee are summarized in the following paragraphs:

Irrespective of the use, there are three important cardinal points that should be given careful attention in the selection of any and all machines of this class. These are in their order: (1) Care in the selection and inspection and acceptance of all material that enters into every part of the machine. (2) Design for strength. (3) Design for production.

With the foregoing fixed firmly in mind, we submit specifications for a Standard Shovel, which we believe will meet the largest requirements for "General Roadway Construction."

Weight. Shovels varying in weight from 25 to 90 tons are recommended. The committee recommends 70 tons.

Capacity of Dipper. Replies received vary from 1½ cu. yd. to 5 cu. yd. The committee recommends 2½ cu. yd.

Steam Pressure. From 100 lb. to 200 lb. is recommended. The committee recommends 120 lb.

Clear Height Above Rail of Shovel Track at Which Dipper Unloads. This height is recommended at different points, varying from 8 ft. to 18 ft. The committee recommends 16 ft.

Depth Below Rail of Shovel Track Dipper Will Dig. The replies vary between 2 ft. and 8 ft. The committee recommends 4 ft.

Number of Movements of Dipper Per Minute from Time of Entering Bank to Entering Bank. From one to six movements are mentioned. The committee recommends three.

Cable or Chain Hoist. Seven replies favor the cable and 27 recommend the chain. This subject has been given very careful

consideration and on account of the economical cost of renewals and repairs the committee recommends cable hoist.

Friction or Cable Swing. Seven vote in favor of friction and thirty-one recommend cable. The committee recommends cable swing.

How Extensive Housing Should be Provided for Engineer, Fireman and Cranesman. The replies received from 26 members recommend permanent housing, while 10 favor temporary protection. We believe that this matter has not been given the attention of manufacturers and others that it demands, although the engineer and fireman are usually well protected, the cranesman is entirely unprotected, and if he is to be retained as a necessary employee, he should be housed. The committee recommends permanent housing for all employes.

Capacity of Tank. Tanks varying from 1,000 gallons to 7,000 gallons are recommended. Believing that it is possible to provide shovel with water at least every twelve hours, the committee recommends 2,000 gallons.

Capacity of Coal Bunker. From one ton to six tons are recommended. Ordinarily a day's supply should be provided, and the committee recommends four tons.

List of Repair Parts Necessary to Carry. From the various replies, the committee recommends the following: 1 hoisting engine cable or chain, 1 thrusting engine cable or chain, 1 swinging engine cable or chain, 1 set dipper teeth, 1 dipper latch, 12 cold shuts, 6 cable clamps, 1 U bolt, duplicate of each sheave on machine, lot assorted bolts and nuts, lot assorted pipes and fittings, lot assorted water glasses.

Give List of Repair Tools Necessary to Cover. 1 blacksmith forge with anvil and complete tools, 1 small bench vise, 3 pipe wrenches (assorted sizes), 3 monkey wrenches (assorted sizes), 6 Chilson wrenches (assorted sizes), 1 ratchet with assorted twist drills, 6 round files (assorted sizes), 1 hack-saw (with twelve blades), 1 set pipe taps and dies, 1 set bolt taps and dies, 6 cold chisels (assorted sizes), 2 machinists' hammers, 2 sledges, 2 switch chains, 2 re-railing frogs, 2 ball-bearing jacks, 1 siphon (complete), 1 axe, 1 hand saw, 1 set triple blocks with rope, 2 lining bars, 1 pinch bar, 6 shovels, 6 picks, 1 coal scoop, 1 flue cleaner, 1 fire hoe, 1 clinker hook, 1 slash bar, 2 hand lanterns, 2 torches, assortment of packing, assorted oil, in cans.

What Spread of Jack Arms. Replies received show a great difference of opinion varying from 14 ft. to 28 ft. Having in mind that it is often necessary to provide for narrow cutting, the committee believes that an extra short-arm should be provided for each shovel. The committee recommends 18 ft.

Recommended Practice in Shovel Operation. The following recommendations were made by the Committee on Roadway of the American Railway Engineering and Maintenance of Way Association at the annual convention of 1917, and are intended to supplement previous recommendations embodied in the 1915 edition of the Manual of the association.

Size of Shovel. For light grading, up to 25,000 cu. yd. per mile, where a shovel can be used economically, a light revolving shovel is to be desired. For 25,000 to 40,000 cu. yd. per mile, a shovel of 50 tons is a good size. For 40,000 to 60,000 cu. yd. per mile, a shovel of 60 to 80 tons is well suited. For anything over 60,000 cu. yd. per mile, the shovel may run up to well over 100 tons economically if its transportation is not too expensive, and if the ground is fit to carry the weight on subgrade during excavation.

The greatest cause of delay in steam-shovel work is in the removal of the excavated material. Too great care and attention cannot be given to securing proper and ample equipment in the matter of cars and locomotives, and in the proper systematization of service, track, transportation and disposal. The economic success of a steam shovel depends, above everything else, on having an empty car always ready to replace a loaded one under the dipper. Too great stress cannot be laid on this point. Careful management, through organization and unceasing superintendence and foresight only, however, can accomplish satisfactory results even with a thoroughly-equipped plant.

As the plant charge against steam-shovel work is always an important item, especially where the haul is long, requiring a large equipment of cars, and locomotives, continuous operation is desirable. For this reason, either three 8-hr. shifts or two 10-hr. shifts are recommended. Where the service is not too trying on the machinery, three 8-hr. shifts are more economical, if they do not upset other parts of the organization. When, however, the work is severe, two 10-hr. shifts are preferable, as this arrangement gives two hours between each shift for repairs and overhaul in the plant. For night work, where electricity is not available, a small turbo-generator set, similar to that used on a locomotive, can be set up on the shovel for lighting the immediate works.

An old locomotive tender is a very valuable adjunct to a steam shovel, especially where delays may be caused from irregularity in coal and water supply.

The greatest cause of stoppage in the shovel proper is due to carelessness or incompetence in the operator. He should see that

his engine-room and all moving parts are kept thoroughly cleaned and accessible. He should train his pit gang to watch the undergearing and track. He must see that his boiler is washed out as often as necessary, depending on the water used, and that his flues, heads and sheets are tight and in repair. He must continually inspect all parts liable to wear or extraordinary strain and make renewals before the accident occurs. He must have a light and accurate hand on the propelling lever and must judge his load on the hoisting chain or cable, especially in an over-powered shovel. Heavy breakage in hoisting chains in such a case is almost always due to an unskilled or careless operator. The mechanical delays on a good shovel operated by a good runner are almost negligible.

Repairs. A good works superintendent or master mechanic can develop good shovel runners if he has time and patience. This, of course, is often difficult on railway work, especially in the Maintenance of Way operations. With average runners, the commonest repairs are as follows:

Hoisting cables.
Hoisting chains.
Swinging cable.
Teeth and tooth bases.
Friction bands and blocks.
"U" bolts or double bolts and yoke.
Pinions (especially shipper shaft).
Dipper latch and hinges.
Dipper stick (in hard digging).
Sheaves and pins (especially at end of boom and padlock block.)
Shipper shaft.
Crankshaft on boom engine.
Eccentric straps.
Bearings.
Arm jacks.
Rack bolts.
Clevis strap between dipper and bail.
Ordinary engine repairs.
Ordinary boiler repairs.
Ordinary pipe fittings.

In the above list of most common repairs much of the trouble is undoubtedly due to lack of proper inspection and judgment in removing worn parts before they actually break, also to careless handling of the shovel when unusual strains arise in heavy digging. Where a good runner is secured the repairs will be very small. Where the work is near a base of supplies, the stock parts carried may be very small. There are also many repairs that may be made by the job blacksmith without special stock.

Repair parts to be stocked for emergencies when shovel is built as recommended, are as follows:

6 cold shuts for hoisting chain.
3 cold shuts for propelling chain.
1 swinging cable.
1 cable sheave and pin.
1 chain sheave and pin.
1 set teeth.
1 tooth base.
1 clevis strap connecting bail and dipper.
2 bolts for yoke, or 2 " U " bolts.
1 set friction blocks.
1 pair each size, bronze bushings.
babbitt, if used anywhere.
1 set piston rings.
6 water glasses.
Miscellaneous assortment of packing.
Miscellaneous assortment of bolts.
Miscellaneous assortment of pipe and fittings.

Tools. The following list of tools is generally recommended. The assortment is very complete and may be reduced at discretion, depending on the proximity of other ready means of supply and repairs:

100-lb. anvil.
1 axe, chopping, 4½-in.
1 bar, buggy, 3-ft.
1 bar, claw.
6 bars, lining.
1 bar, slice, fire, 5-ft.
1 set blacksmith tools.
2 blocks, snatch, 6-in.
Set of bolt taps and dies, with holders.
1 brush, chain, long handle.
2 buckets, G. I., 2-gal.
1 cable, ⅝-in., 60 ft. long.
1 can, oil supply, 1-gal. (kerosene).
3 carriers, timber.
6 chisels (two flat, two round, two cape).
2 containers, oil, 5-gal.
1 cooler, water, 8 gal.
2 cups, drinking, enamel.
1 cutter, pipe.
1 cutter, gage glass.
Set of twist drills.
1 flue cleaner.
Forge, blacksmith, portable (with coal).
1 gage, track.
1 pair frogs, rerailing.
Set of taps and dies, with holders.
1 hacksaw, adjustable, 8-in. to 12-in.
2 hammers, B. P., 1½ to 2 lb.
6 hammers, sledge, double-face, 8-lb.
1 hammer, sledge, double-face, 16-lb.
1 hoe, fire, 5-ft.
50 ft. hose, canvas, 1¼-in.
2 jacks, ball-bearing (size dependent on shovel).
1 lantern, hand.
2 oilers, long spout.
3 padlocks.
3 picks, clay.
1 pot, tallow.
1 rake, fire, 5-ft.
1 ratchet, drill.
1 saw, crosscut (two-man), 5-ft.
1 saw, hand, crosscut, 26-in.

1 screwdriver, 12-in.
6 shovels, round point, short handle, No. 2.
1 shovel, scoop, No. 3.
1 vise, combination, pipe and bench.
4 wrenches, monkey, 6-in., 8-in., 12-in. and 18-in.
4 wrenches, Stillson, 6-in., 18-in., 24-in. and 36-in.
1 set wrenches, single-end, ½-in. to 2½-in.

Locomotives. The type and size of locomotives used on steam-shovel work must depend on the character of the work, weight of trains, the length of haul and the local conditions. On maintenance work, ordinary road engines are usually well suited, especially if an ample tail track is provided in the pit that too much shunting is not required. On construction, where the track is apt to be bad and curves abrupt, the 4- or 6-wheeled saddle-tank type is preferable, at least near the shovel. If the haul is long and the track is fair, heavier locomotives should be used in transportation.

In general, on construction where the tracks are inclined to be rough and curves sharp, the shorter the wheel base on a locomotive the better, within limits. Where road engines, or even heavy switch engines, are used, there is always danger of derailments and frame breakage. Where "dinkeys" are used, it is well to pay special attention to springs, brakes and the location of the center of gravity with reference to the wheel base. Some makes are so balanced that under heavy loads and on steep grades, two wheels are sometimes lifted clear off the track, with the natural resulting delays, if not damage.

Track. The shovel track should be made up of 6-ft. sections, with strap connections. Bridles of ½-in. by 2-in. iron should be used, with wedge grips. A notched tie should be used as a check, behind the front trucks, supported by steel saddle clamps attached to the rail with wedged grips. Similar clamps should be placed before the front wheel without tie check. Nothing less than 60-lb. rail should be used under a shovel, and heavier rail should be used under the larger models. No spikes are used.

On the muck track in tunnels standard-length rails are used, spiked to the ties. Where no tail track is possible and the excavation is at a breast, drive rails are very useful. These consist of half-length rails laid on their sides, with the ball of the rail against the inside of the web of the last rail spiked down. As the breast is cleared away, these short rails are driven ahead and the cars are run out on the balls of the capsized rails. When a half-length is thus driven out, it is turned right side up and spiked lightly in position and the other half-length driven out in a similar manner.

Preventing Freezing of Dump Car Bottoms. *Engineering and Contracting*, Apr. 17, 1918, gives the following:

A hot salt solution is employed on the Mesabi Range for preventing the freezing of the bottoms of the dump cars used in connection with the steam shovel stripping. A rectangular wooden box of 2,000 gal. to 2,500 gal. capacity is used for a salt tank. The salt is added to the water until a solution is obtained, the common method being to add salt until the solution will float a potato. Steam to keep the solution at a boiling point is obtained from a near-by power or pumping plant or from a small vertical boiler especially installed for this purpose. The cars are sprinkled with the hot solution by means of a hose.

Management of Steam Shovel Work. The following is taken from the "Handbook of Steam Shovel Work" published by the Bucyrus Company. This volume contains many examples of shovel work together with cost data as reported to the Bucyrus Company by the Construction Service Co. Some of these examples are quoted by numbers so that they may be compared with the diagrams.

Lost Time. Steam shovel operation is rarely a continuous performance, so far as concerns the shovel itself. There are always delays, some of which are due to breakages on the shovel itself and some to interruptions of one of the collateral processes, breaking or transportation. The most costly of these has been where the shovel was loading blasted rock, and because of imperfect breaking the shovel had to stop from time to time to allow drilling and blasting under the dipper. In one case the interruptions from this cause amounted to nearly 50%, which in an 8-hr. day allowed the shovel only four hours for actual work. Under such conditions the transportation facilities must be adequate to keep the shovel working full time, so that delays to the shovel increase the cost of transportation correspondingly.

Accidents to the transportation department, due to bad condition of the equipment, rolling stock, or track, cost just as much as delays of the same duration caused by shovel breakdowns. Reserve equipment will often save money in such a situation, but the best safeguard is to give to one man the facilities and responsibility for seeing that all equipment be kept in first class repair. It is customary for shovel crews to make their repairs to the shovel out of working hours and on Sundays whenever possible. On heavy rock work, where many repairs are needed, the crews often have to work nearly every Sunday for an entire season, and the consequent lack of rest and recreation is likely to tell on the men's working efficiency.

Stopping to "chain out" boulders on heavy rock work in shale or the schist of Manhattan Island is likely to account for a lost time bill of 20% or more, and presents a most aggravating and discouraging obstacle to good work. In such cases several extra chains should be provided, and two or three men constantly employed in putting them on the boulders as fast as possible while the shovel is working. Even if these men are often idle for several minutes at a time, the result, in shovel output, of their services is worth more than their pay. After estimating how many cents each dipper swing is worth in pay yardage, it is a simple matter to calculate how much should be spent in keeping the dipper working. Mud-capping the boulders, to save "chaining out," is desirable if it can be done without too much delay. Usually it will be found cheaper in the end to keep a man or two drilling block holes, especially if the facilities permit the use of a small power drill. When thus drilled the boulders can be cracked with small charges and with almost no interruption to the shovel work. With the small drill (like a riveting gun) the holes may be put in on the side of the boulder away from the shovel, if that side can be reached, drilling about 6 to 10 in. deep, tamping with blue clay forced in with the thumbs and fired with a fuse. Very small charges of a rather high powder (50 or 60%) should be used.

A list of the various causes of delay should be kept by the shovel runner, and reported daily, with the duration of each, so that the relative importance of the different causes may be known, and a standard remedy adopted. Whenever such a remedy is needed, the shovel runner can call for it by a whistle signal. The following is a convenient code for these signals, a long toot being indicated by a dash, a short one by a dot:

—	Pit crew get ready to move shovel.
— ·	Get ready to mud cap.
— · ·	Get ready to block hole.
— · · —	We need coal.
· — ·	We need water.
· ·	Waiting for cars (useful to help in spotting cars when dinkey man cannot see hand signals).
·	Stop.
— — —	All ready to blast.
· · · ·	Fire.
· · — · ·	Cars off the track.
· · ·	Back up.
— — · ·	Shovel has broken down.
· — —	Superintendent's call.

A code of these signals in the shovel cab, and one in the hands of each foreman, will be sure to save money by the elimination of the preventable delays.

Kind of Labor Running a shovel is a highly trained and a highly paid specialty, and as a general thing shovel runners are intelligent and conscientious, but a good deal depends on the way in which a runner and his craneman work together. If they should be of incompatible dispositions it is often better to move one of them to some other shovel than to have them work badly together. They must have considerable confidence in each other in order for the attainment of the highest efficiency.

We cannot too strongly emphasize the importance of selecting the most skillful shovel runners and cranemen. The loss of money caused by indifferent ability in these positions may easily be several times as much as the wages of the men themselves.

We have elsewhere shown the economic effect of efficiency in moving the shovel. For this reason the pit crew should be made up of picked men, one of them getting a little more pay than the others perhaps and having authority over them. Thorough organization here may be worth half of the wages of the pit crew. Of great importance in many classes of work is the dump gang, which usually receives but scant attention. In sandy material there should be no difficulty in dumping the cars with great regularity and returning them to the shovel on time, but with clay mixed with boulders a good dump foreman and a lively gang are necessary for good work. The men must realize that they are part of a large machine and that their own delays will impede their fellow workmen. For this reason it is often well to alternate the foreman and some of the men between the different positions. A foreman on the dump will better realize what is expected of him after he has had experience in the pit and on the track laying. Some of the more intelligent men will also be benefited in like manner, while others of less intelligence will not.

Estimating. For purposes of estimating, in order not to forget anything and to facilitate a logical arrangement of the various costs that occur on the work, it is important to have some standard classification of expenses. The ordinary costs are included in the following list, which is used by the Construction Service Company as a standard guide, and which will be found useful as a guide to properly subdivide the cost keeping in the field, and as an aid to the bookkeeper. By using the symbols opposite each name they can be readily and easily referred to. We have found that the mnemonic method is much easier to remember and more satisfactory in operation than a numerical

system. It has been in use for some time and it is proving very satisfactory.

STANDARD CLASSIFICATION OF EXPENSES

Classification I. Main Classification of Expenses.

O	Office	Overhead.
X	Miscellaneous	
F	Field	Direct.
U	Sub-contract	

Classification II. Distribution of Classification I.

L	Labor directly productive.
Lh	Hourly labor.
Lw	Weekly labor.
Lm	Monthly labor.
Li	Incidental labor.
F	Labor superintending.
M	Material.
S	Supplies.
X	Miscellaneous.

Classification III. Distribution of Classification II.

R	Repairs	Maintenance.
D	Depreciation	
I	Interest	
S	Storage	
H	Hire or rent	Incidental.
T	Transportation	
O	Organization or preparatory	
X	Miscellaneous.	
C	Charity or accidents	
B	Bonus or discounts	
Z	Legal and medical	
P	Publicity or advertising	
A	Accident insurance	
F	Fire insurance	
Q	Theft insurance	
G	Bond to guarantee contract	

Classification IV. Application of Classifications II and III.

E	Equipment or plant.
T	Tools.
B	Buildings.
C	Cash capital.
X	Miscellaneous.

Classification V. Field Processes.

B	Breaking (loosening).
C	Construction.
D	Dumping.
G	Grubbing.
L	Loading.
M	Mixing.
	Protection.
R	Ramming and rolling.
S	Spreading.
T	Transportation.
X	Miscellaneous.

Classification VI. Type of work.

C	Concrete masonry.
E	Earth.
L	Liquids.
	Brick and mortar.
R	Rock.
W	Woodwork.

We also give in this chapter some charts made up from our observations, which will be useful in helping to estimate the costs on steam shovel work. Rates of wages must be ascertained for the particular locality in which the work is to be done, and with reference to the condition of the labor market. It may be

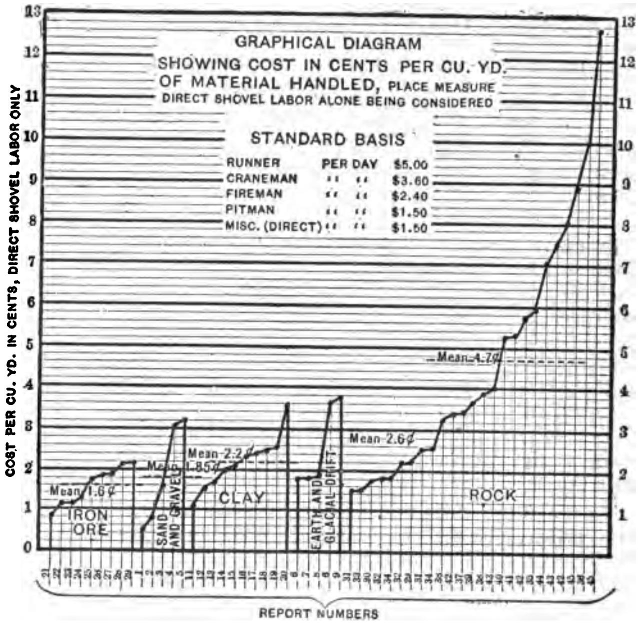


Fig. 33. Diagram Showing Cost.

TABLE OF RATES OF WAGES. DIRECT LABOR

Bucyrus Shovels

Occupation	No. Obs.	Minimum	Average	Maximum
Runner	41	$75.00 per month	$135.00 per month	$175.00 per month
Craneman .	41	55.00 per month	96.00 per month	125.00 per month
Fireman ...	38	50.00 per month	62.00 per month	87.00 per month
Coalman ...	8	1.40 per day	1.47 per day	1.50 per day
Pitman	39	1.40 per day	1.90 per day	3.50 per day

noted that certain report numbers are quoted in these charts, the corresponding reports not being found elsewhere in this volume. In such cases the information is on file, but is not published in detail owing to objection on the part of the company or individual operating the shovels.

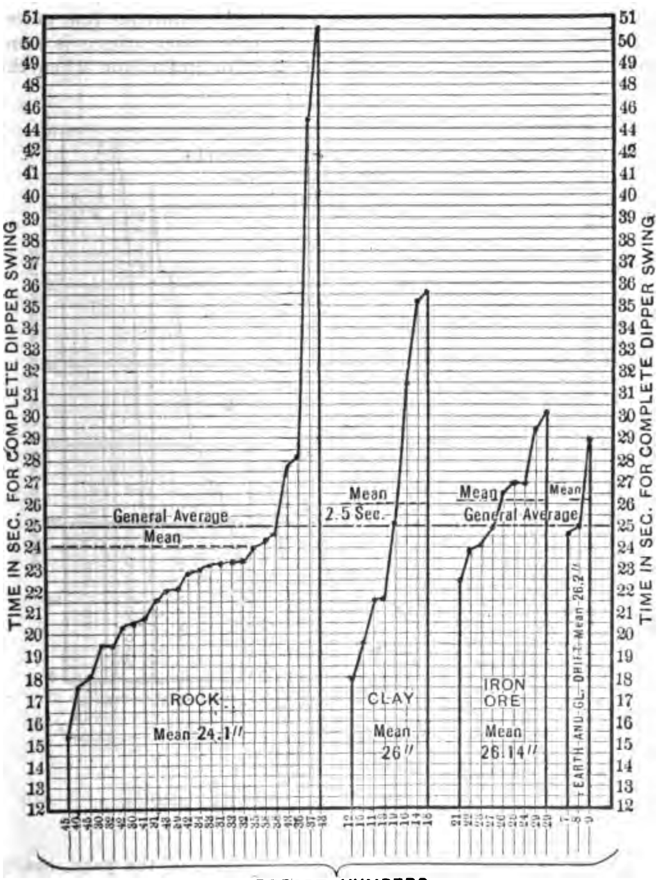


Fig. 34. Diagram of Time in Seconds for Complete Upper Swing.

Steam Shovel Work in Sand and Gravel. Most of this work is likely to be in a borrow pit, where a large area is to be excavated, and where the installation is of a semi-permanent nature. Many of the banks are very high, requiring few moves of the shovel, and in some cases, especially where there is some cementing material mixed with the sand or gravel, or when the

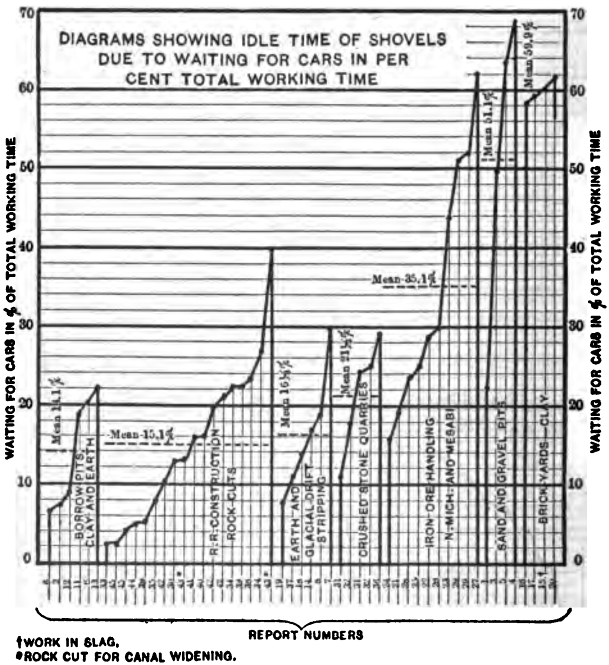
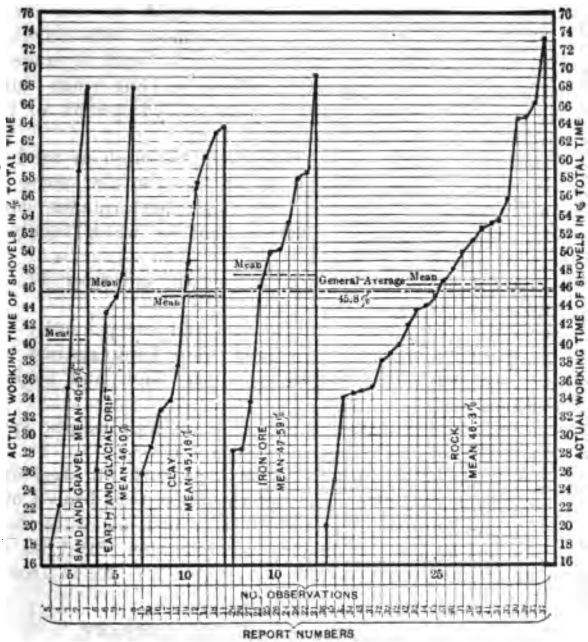


Fig. 35. Diagram Showing Idle Time of Shovels.

cementing is done by ice in the spring or fall of the year, heavy and dangerous land slides are possible.

From an operating standpoint sand is an ideal material to handle, except when very fine and in heavy winds, in which cases a high pressure stream of water from a hose with spray attachment, if water be plentiful, will greatly help to keep the sand out of the eyes of the men. Sand in a freshly dug bank is



Material	Min.	Average	Max.	No. Obs.
Sand and gravel	18.2	40.5	67.6	5
Earth and drift	26.5	46.0	67.8	5
Clay	26.0	45.16	63.4	10
Iron ore	28.4	47.59	69.3	10
Rock	20.4	46.3	73.3	25

Fig. 36. Diagram Showing Actual Shovel Working Time in % of Total Time.

quite often naturally moist. In railroad work a good deal of this material is loaded on flat cars with or without side-boards, and it is often difficult to make close estimates of the amounts handled. We have found it an excellent method to weigh the amount of material that will fill a half cubic yard box, at

average dryness, and then weigh several trains of cars of the material, which can easily and conveniently be done. From records obtained in 1898, average gravel used for railway ballast, fair quality, moderately clean, weighed 3,248 lb. per cu. yd., rather dry, and the average flat car without side-boards contained 9.4 cu. yd. The length in a train of such average cars was 36 ft. center to center of couplers, so that when dumped from the train the ballast averaged 0.26 cu. yd. per ft. of track. This was sufficient to raise one track 5 in.

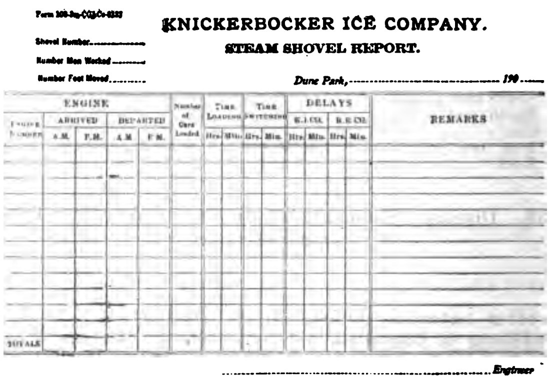
Free running dry sand will not stand up so high in the bucket or on the cars as when it is quite wet or contains some little cementing material. Therefore, the best performance can be looked for where there is a little cement or water evenly distributed in the bank.

Report No. 1. Shovel No. 612, inspected September 11, 1909, Dune Park, Ind.

The material was all of uniform size and exceptionally clean, sharp, white and rather small grained. The bank against which the shovel worked was fully 60 to 70 ft. high and sloped at about one on two.

The material was loaded upon gondola cars supplied and spotted by the Lake Shore & Michigan Southern Railway.

The shovel was of the usual 70-ton type with all steel dipper handle and boom, the latter being of the truss type braced on the sides. A 2½-yd. dipper was used. This, instead of teeth, had a long steel lip or "cutter blade," so that when filled its capacity was increased to about 3¼ yd. Water was taken from the



KNICKERBOCKER ICE COMPANY.

STEAM SHOVEL REPORT.

Shovel Number..............

Number Men Worked..........

Number Feet Moved..........

Dune Park,.............................. 190....

Engine Number	Engine Arrived A.M.	Engine Arrived P.M.	Engine Departed A.M.	Engine Departed P.M.	Number of Cars Loaded	Time Loading Hrs.	Time Loading Min.	Time Switching Hrs.	Time Switching Min.	Delays K.I.Co. Hrs.	Delays K.I.Co. Min.	Delays R.R.Co. Hrs.	Delays R.R.Co. Min.	Remarks
TOTALS														

....Engineer

Fig. 37. Report Form for Steam Shovel Work.

ground by means of a pipe sunk therein and a pump on the shovel, which was digging to water level only.

Cost keeping. The time sheet was made in duplicate and was sent to the main office, where the payroll was made up and the total amount charged to the job. The steam shovel report also went to the main office every day. This was made out by the steam shovel engineer, but was copied by the clerk to obtain a clean sheet. A facsimile of such a report blank is given in Fig. 37.

OBSERVATIONS

Weight ......70 tons, shipping weight without coal and water
Capacity of dipper..................3.27 cu. yd., including lip
Depth of dipper (water measure) ....51 in.
Depth of dipper including lip ....81½ in.
Cubic yards excavated (place measure) in 8 hr...........3,300
Cubic yards per car (place measure).........average 11.2 yd.

	Per cent.
Actual working	67.6
Spotting cars	0.7
Waiting for cars	22.6
Moving shovel	6.8
Miscellaneous delays, including 8 minutes clearing track	2.3
Total time under observation, 481 min.	100.0

DIRECT LABOR DISTRIBUTION

	Per day
1 runner	$ 5.00
1 craneman	3.60
1 fireman	2.40
3 pitmen	4.50
3 spreaders	4.50
Watchman	1.50
Timekeeper	2.00
Shop engineer	2.00
1 machinist	3.00
1 car repairer	2.00
Total cost of labor per day	$30.50
Cost per cu. yd., ct.	0.93

Report No. 2. Shovel No. 1118, inspected July 16, 1909, at Kent, Ohio.

This work was part of that undertaken in the relocation of the Wheeling and Lake Erie R. R. at Kent, Ohio, and was done by John B. Carter under contract. A prize of $5 was offered to the dinkey runner who made the best time spotting cars during the afternoon's work.

OBSERVATIONS

Material is fine gravel with occasional strata of sand. Ideal material to handle. Weather fair after heavy rain during night.

Type of shovel ....Standard gauge 70 C
Size of bucket ....2½ yd.

Length of shift	10 hr.
Coal used	3¾ tons per 24 hr.
Water used	300 gallons per hr.
Narrow gauge track 3 ft., 55-lb. rails for cars.	
Kind and size of cars used	K. & J., 4 yd.
Kind and size of dinkey	Vulcan, 16-ton
Length of haul	Max. 3,500 ft., min. 2,300 ft.
Number of trains	3

	Per cent.
Actual working	58.9
Waiting for cars	7.4
Moving shovel	13.2
Miscellaneous delays	(20.5)
Coaling	1.2
Repairing track	1.1
Repairing track	.9
Pulling track on dumps	17.1
Minor repairs	.2
Total time under observation	100.0

Average number of cars loaded per day (average of 85 days) = 516 @ 4¼ yd.

Average number of cubic yards loaded per day (average of 85 days) = 2,193.

	Standard basis
1 runner	$ 5.00
1 craneman	3.60
1 fireman	2.40
3 dinkeymen	7.80
3 brakemen	4.50
4 pitmen	6.00
9 dumpmen	13.50
1 dump foreman	2.00
1 pipeman	1.50
1 smith	2.50
1 smith helper	1.50
1 watchman	1.50
Cost of labor per day	$51.80

Time Study Reductions	Number of Observations	Minimum Min.	Minimum Sec.	Mean Min.	Mean Sec.	Maximum Min.	Maximum Sec.
Time for moving up, shovel idle	19	1	20	2	54	5	45
Time between moves, shovel working	20	7	35	12	23	14	..
Time between trains	21	..	55	1	29	2	05
Time per train loading	36	6	07	6	52	8	10
Time per dipper	21	..	16	..	17	..	19
Number of dippers to move	20	24	..	..	42.3	..	48
Number of dippers per train	36	24	..	..	24.2	..	26
Number of dippers per car	432	..	..	..	2.02	..	..

The total loading time of the contest was 215 min. 57 sec., and in this time 770 complete dipper swings were made, and 384 cars at 4 cu. yd. each were loaded.

Shovel No. 1118 was moved back on standard rails 30 ft. in length, only 6 rails being used, and the method employed was as follows:

When the shovel had finished its cut, a track 90 ft. long was laid behind it joining the regular shovel track made up of short sections. The shovel was then backed to the end of this track, and as soon as it had passed off the first rail-length the rails were picked up by four men and thrown over the loading track. On this track stood a dinkey with a 6 by 8-in. piece fastened to its front end, and long enough to extend about 6 ft. from the side of the dinkey on the shovel side of the track. At the end of this was a piece of ¾-in. cable, wrapped securely around the timber, and with a loose end about 10 ft. long. At the loose end of the cable was a hook made of material small enough to be inserted in the bolt holes in the rail.

When a rail was moved over toward the loading truck this hook was fastened to the rail and the dinkey then dragged the rail to the rear of the shovel. While the four men were moving the rails and the dinkey was dragging them, three other men were gathering up the ties and putting them in piles of three or four each, fastening them with chains. The ties were dragged by mule team to a place in rear of the shovel where they were spaced by two men and made ready to receive the rails. As soon as sufficient ties for a rail length of track were laid, the rails that had just been brought back by the dinkey were placed upon them and fastened to the rails on which the shovel stood, and were connected and spaced by four regular track bridles. The shovel then moved back one rail length and so left a rail length in front of its position uncovered, this being then torn up and moved back — the rails by the dinkey and the ties by the mules.

The force engaged included the

Shovel engineer	1 Foreman
Craneman	1 Mule team and driver
Fireman	8 Men moving rails
Dinkey engineer	5 Men moving ties
Dinkey brakeman	4 Pitmen bolting track, etc.

at a total labor cost of $46.60 per day.

It took 1 hr. 10 min., to move the shovel back 300 ft. in this manner or .1167 of a day.

0.1167 x $46.60 = $5.44 to move 300 ft., or 1.81 ct. per ft.

Preparatory cost was $1,500; includes moving shovel 2,500 ft. from railroad tracks on practically same grade as bottom of pit.

Distance of move in pit laterally for each bank averages 30 ft. for eleven moves.

ACTUAL RATIOS

$$\frac{\text{Water consumption, pounds}}{\text{Coal consumption, pounds}} = \frac{60,000}{7,500} = 8.00.$$

Report No. 3. Shovel No. 611, Inspected Sept. 14, 1909, at Gary, Ind.

The shovel itself had no features that would distinguish it from any of the others of the 70-ton class, but the method of blocking up the rear trucks was different from the usual practice. These were raised 20 in. while the front ones were elevated only the usual 6 in. The reason given for this by the runner was that the boom "swung better." When swung loaded over the cars it could be stopped more quickly and would swing back in less time than when blocked evenly. The boom was of the truss type with lattice side bracing, and both it and the dipper handle were made entirely of steel. Water was taken from the locomotive.

OBSERVATIONS

Capacity of dipper ....3 cu. yd.
Area of section of face ....755 sq .ft.
Height of face ....24 ft. to zero
Cubic yards per car ....21.1 place measure (average)

	Per cent.
Actual working	35.4
Spotting cars	0.3
Waiting for cars	48.8
Moving shovel	5.1
Miscellaneous delays	1.3
Idle-engineer looking after fire	3.8
Pitmen loosening bank	0.2
Waiting for cars to pull out	0.4
Fixing valve on crane engine	1.1
Taking water	1.8
Taking coal	1.8
Total time under observation, 547 min.	100.0

THE SHOVEL CREW PAY ON STANDARD BASIS

Runner	$ 5.00
Cranemen	3.60
Firemen	2.40
4 pitmen	6.00
6 trackmen	9.00
Labor cost per day for excavating	$26.00

Cubic yards loaded on day of observation 1,602

Cost of loading per cubic yard (direct labor only), $\frac{\$26.00}{1,602}$

= 1.62 cents per cubic yard.

Steam Shovel Work in Earth and Glacial Drift. The peculiarity of this material for steam shovel work is that it varies

much more in consistency than sand and gravel, may be difficult to break up, and often contains boulders of considerable size. It is the usual practice to attack it with teeth instead of a steel lip on the bucket. When wet, the material is likely to stick to the bucket, and particularly to the bottoms of dump cars, making it difficult to remove in dumping, and being likely to dry or freeze into a hard cake. For this reason it is important to clean and scrape car bottoms at night.

Because of the prevalence of boulders, which cause irregular loading of the bucket and of the cars, this material will not be likely to average quite as many yards, place measure, per car of the same size as will sand or "good" gravel.

Fig. 38. 1¼-yd. Bucket with 18-in. Lip Added, Increasing Capacity to About 2 Yd. Used on 45-Ton Shovel near South Bend, Ind.

When the large boulders occur, necessitating the use of chains and hooks, or even mud capping with dynamite to reduce their size, the work is necessarily much delayed and the cost becomes excessive.

Sometimes a good sized boulder may roll down the slope and injure one of the pitmen, who are therefore more cautious than when working in sand, and consequently slower.

In estimating upon this material the ground should be gone over with care by the man who is to make the estimates, and a computation made of the number of boulders above the limiting size that are likely to be encountered. A shovel with large bucket

is advisable for this work, since the delays from boulders are thus minimized.

Report No. 6. Shovel No. 893, Inspected July 14 and 15, 1909, at Long Island City, N. Y.

This shovel had standard gauge railroad car wheels, weighed seventy tons and was about three years old. It had been overhauled several times and was in good condition.

It will be noticed under the "Labor Distribution" table that there were two more pitmen than is usual. The duties of the engineer consisted in superintending everything about the shovel in a general way and, in co-operation with the craneman, running the shovel. His word was law in anything connected with the shovel. The craneman operated the dipper engine and dumped the dipper. He also directly supervised the operation of moving forward, but on this shovel did none of the actual work. The pitman receiving $1.75 was a general handy man and was foreman of the pitmen, although he did the same work as they.

While the shovel was operating, the pitmen were engaged in taking up the rails and ties behind it and carrying them to a convenient place ahead, so that they could be readily laid. The ties were thrown in front of the forward trucks, and as soon as the dipper dug high and far enough away, the pitmen laid the stringers and then rolled the ties into place so that as soon as the shovel was ready to move, all that remained to be done was to place and clamp them to the rails, and set the jacks. Under the head of "Time Study" will be found the percentage of the total time consumed in moving forward.

As has been explained, moving the shovel forward is an intermittent process. So far as is possible, however, the move back to enter a new cut is made continuous. This necessitates an unbroken track behind the shovel. In this particular case it took all morning and part of the afternoon to thus clear the way and lay the ties and rails. The time required for such a process is of course dependent on the distance the shovel must be moved back and also upon the number of curves encountered. Great care should always be exercised in having the bridle rods in proper adjustment, especially on the curves, for otherwise the shovel will be likely to leave the track, causing annoying delays. Here, as will be seen in the "Time Study," the actual moving back occupied 106 min., and 48½ min. were necessary to get things into running order after the backward journey.

Coal for the shovel was brought in by the dinkeys, dumped near by, and carried from the dump by a laborer. For this purpose an ordinary nail keg was used, and by having the man keep count of the number of kegs, the consumption to within a

tenth of a ton was obtained. On the first day this amounted to 2.2 tons and on the second to 2.7 tons.

In order to be able from time to time to tell whether any part of the work was costing more than it should, the engineer in charge had kept very close cost accounts, and he very kindly explained his methods.

The timekeeper on this work had two books, using them alternately. He did not write in the names or the numbers of the men before leaving the office, but as he found the men on the work he jotted their numbers or names one below the other just as he came to them, starting with a new page every day. The following day this book was left in the office and the clerical force compared the timekeeper's record with the foreman's reports. If there was any discrepancy it was called to the timekeeper's attention and he looked into the matter.

From these records the office force made up a daily statement showing the labor employed, the rate of wages, the amounts, and the nature of the work. Material used was kept account of by the amounts delivered to each machine or foreman, as shown by the storekeeper's daily report.

From these reports the engineer himself made up the distribution. This, however, did not follow any definite scheme such as the schedule employed by the Construction Service Company, but consisted in crediting to each item, such as grading, surfacing, mixing concrete, shovel No. 1, etc., its quota of labor and materials used, and from these data the unit costs were computed by the engineer, so that no one else has access to them. Superintendence, insurance, interest, and other items that could not be charged directly to any one operation were distributed according to the percentage of the total labor cost involved. Superintendence had been found to be about 6 to 6½% of the labor cost. The cost and amount of coal, oil, and cotton waste supplied to any machine over a definite period was divided by the number of working days and by the number of yards excavated or hauled to find the unit quantities and costs. Depreciation was not considered until the end of the job. With the exception of the foreman's reports and the daily statement of the timekeeper, no printed forms were used for this work.

The general plan of the track layout, shown in Fig. 39 is the ideal arrangement for feeding cars to a shovel as, with wide awake signalmen and dinkey engineers and plenty of cars, there should be no more reason for losing time in spotting trains than in spotting cars, for as soon as a train is loaded and pulls out another follows right into its place, and by loading the end car first no time need be lost. With the exception of not always

having enough trains on hand, this is what would happen on this work, and when the trains did follow one another very little time was lost. This arrangement is particularly suitable when the number of moves of the shovel is a minimum for then the idle time of the dinkeys would be a minimum also.

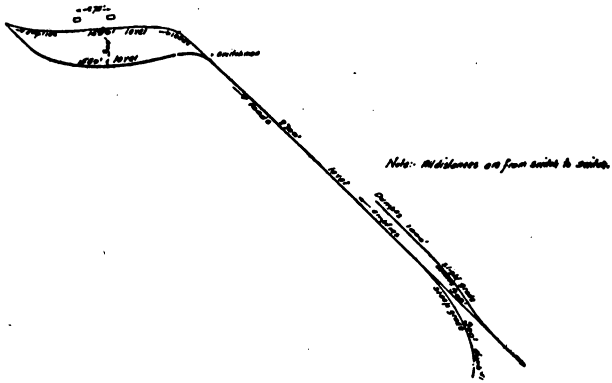


Fig. 39. Track Arrangement Shovel 893. Report No. 6.

The total "run around" was 7,300 ft., 6,600 ft. and 6,300 ft., depending upon the dump, as indicated in the sketch (Fig. 39). The dinkeys weighed 18 tons each and the cars were the usual 4.17-yd. side dump cars. These cars hold about 3.6 cu. yd. when heaped full. No method of breaking was provided or needed.

	Per cent.
Actual working	43.4
Spotting cars	0.0
Waiting for cars	20.4
Moving shovel	17.9
Idle time — rain	1.2
Repairing boom	2.8
Clearing track after blast	6.1
Miscellaneous time — clearing bank	2.3
Blasting	0.4
Moving boulders	3.0
Boulder on track	1.5
Loosening bank	0.7
Jacking up	0.3
Total time under observation, 600 min.	100.0

1,705 cu. yd. per day during 1908.

Standard Basis — Second Day

Runner	$ 5.00
Craneman	3.60
Fireman	2.40
1 pitman	1.75
8 pitmen	12.00

Standard Basis — *Continued*

1 coalman	1.50
3 locomotive engineers	7.80
3 locomotive brakemen	4.50
1 switchman	1.50
4 laborers, blasting	6.00
1 foreman, blasting	2.00
35 laborers, 3 dumps	52.50
3 foremen, 3 dumps	6.00
1 superintendent	6.00
Total cost of labor per day	$112.55
Cost of labor per cubic yard, cents	7.89

From the record which follows:

Average cubic yards excavated per day during 1908	1,705

$$\frac{\text{Average cost loading labor per day}}{\text{Number cubic yards per day}} = \frac{\$24.75}{1{,}705} = 1.45 \text{ ct. per cu. yd.}$$

Month	Total days worked	Number of stormy days	Actual No. days worked less all delays
*January	26	1	21.10
*February	23	1	18.17
March	21	3	18.73
April	25	1	20.65
May	25	1	21.58
June	25	0	23.28
July	26	0	22.38
August	1		
September	0	0	
October	25	0	18.64
November	25	0	13.92
*December	24	0	17.35
Total	246	7	195.80

* 9-hr. days during January, February and December.

Steam Shovel Work in Clay. Clay is more susceptible to moisture than any of the other materials considered in this volume. It will stand with a nearly vertical face before excavation and can be dug very readily when fairly dry. When rather wet it is sticky and offers great resistance to the lifting motion of the bucket. With a powerful engine this is of no great disadvantage, since the resistance is smooth and does not rack the boom and shipper shaft. In the pit, however, the discomfort attendant upon working in this wet material is very considerable. To handle it wet with hand shovels is laborious, as it sticks to the bowl of the shovel and tries to take the shovel and the shoveler with it when cast. A hole or two punched in the bowl will often afford much relief to the men. This material containing practically no voids, is very heavy, and, owing to its stiffness, a large amount in comparison with sand or gravel can be loaded upon a car. Ton for ton, it is economical to transport for this reason.

In wet weather it is apt to cling like flypaper to the car and delay the dumping operation. When handled with a toothed dipper it is liable to get between the teeth in chunks and cling to them when dumping into the car, so that only a portion of the dipper load is released for each swing. This is very irritating to the men and expensive to the management.

Report No. 11. Shovel No. 1119, Inspected July 15, 1909, at Kent, Ohio.

OBSERVATIONS

Material. Clay mixed with sand with occasional sand pockets. When dry could be handled easily but when wet it was very gummy and stuck in dipper badly. Some quicksand.

Type of shovel	70 C Bucyrus
Size of bucket	2½ yd.
Length of shift	10 hr.
Coal used	3 tons in 10 hr.
Water used	3,500 gallons in 10 hr.
Boiler is cleaned once a month.	
Narrow gauge 3 track, 55-lb. rail.	
Kind and size of cars used	K. & J., 4-yd.
Kind and size of dinkey	Vulcan, 16-ton
Length of haul	Max. 2,700 ft., min. 2,000 ft.
Number of trains	2 — 12 cars

Cars figure 4¼ yd. each according to this record and monthly estimate for first three months.

This shovel cut into right of way for several days and was then turned into borrow pit. The preparatory cost of cutting into right of way was $400 and to cut into borrow pit $1,200 more. Shovel was delayed from May 19th to May 26th, on account of right of way difficulties. Total preparatory costs and cost of delay were said to be $3,000.

	Per cent.
Actual working	63.4
Spotting cars	...
Waiting for cars	19.1
Moving shovel	13.6
Miscellaneous delays	3.9
Total time under observation, 362 min.	100.0

From the records which follow:

Number of carloads excavated per day (average of 36 days) 380 @ 4¼ yd.

Cubic yards loaded per day (average of 36 days) 380 x 4.25 x 90* = 1,450 cu. yd.

$$* \; 0.90 = \text{ratio of } \frac{\text{Place measure}}{\text{Water measure}}$$

Standard Basis

Runner	$ 5.00
Craneman	3.60
Fireman	2.40
4 pitmen	6.00

Dump foreman	2.00
7 dumpmen	10.50
2 brakemen	3.00
2 dinkeymen	5.20
1 pipeman	1.50
1 watchman	1.50
Total cost of direct labor per day	$40.70
Cost per cu. yd. (ct.)	2.81

Report No. 12. Shovel No. 843, Inspected July 10, 1909, at Cleveland, Ohio.

This shovel was working during July on a deep cut on the L. S. & M. S. cut-off south of Cleveland, Ohio, where the line runs through Brooklyn.

The finished cut was to be for a four-track line and the bench on which the shovel was working at the time was within 3 ft. of finished sub-grade. On the south side of the cut the excavation was to grade and one cut more was needed on the middle bench to finish the work. The remaining 3 ft. to the sub-grade, on the north side was to be taken out by hand.

The shovel was to go through the cut once more on the center line, or a little to the left of it, so as to take the 7-ft. heading to grade, and as much of the 3-ft. cut on the north side as possible.

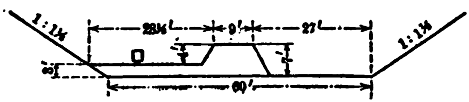


Fig. 40. Typical Cross Section.

Material. The material was dry clay and disintegrated shale. When the dipper was run into the bank the material broke up into fine flake spalls almost like small shells, and as it was perfectly dry it could be handled with the utmost ease. When the shovel was near the bank after moving up, the dipper could penetrate to half its depth by inertia alone before the crowding engine was started, thus insuring a full dipper at every swing even though it might be brought but half way up by the hoisting engine. The dipper was dumped easily and was completely emptied at each dumping. When an attempt was made to heap a car, material was almost sure to be lost, as it was so light and flaky and so lacked cohesion that it would run over the side. For the same reason the dipper had to be spotted very carefully before it was dumped.

In spite of whatever care the shovel runner exercised in dumping his dipper and the brakeman in spotting his cars, the track had to be cleaned after each train pulled out. This, of course,

was done by the pitmen, and often, when moving up occurred between trains, they were able to get the track clear and look after their regular duties as well.

When moving up the shovel, a 2-in. pipe was used to swing the jack blocks clear of the ground instead of the ordinary wooden pole. This pipe was held in a bracket attached to the jack arm and had a collar about 4 in. from its end, which kept the chain that suspended the jack block from slipping along the pipe. This pipe was held by the bracket and was always in place, there being little danger of its breaking or splitting, as is often the case with wooden poles.

The average haul was about three miles over very rough track. Three standard railroad locomotives were used. The cars were the most modern type of Western "air dumps" of 12-yd. capacity. They were built in two sizes, there being 40 cars with bodies 18 ft. 9 in. long and five cars with bodies 26 ft. in length. All were double truck, two-side dumps with wooden bodies. Trains were composed of 15 cars each. Ten men worked on the dump. The material was unloaded on one side over a bank about 40 ft. high. When the track was not near the edge of the bank a spreader was used. This consisted of a steel scraper plate with one end hinged on the trucks of a flat car and the outer end supported by a line from a block on the floor of the car. The spread and depth of cut could be regulated by one man on the car, but often the operator of the spreader was helped by the brakeman of the train. The regular dump train engine was used in operating the spreader.

OBSERVATIONS

Shovel	70-ton Bucyrus
Size of bucket	2½ yd.
Length of shift	10 hr.
Coal used	2½ to 2¾ tons per day
Water used	6,000 gallons per day
Standard gauge track; 55-lb. rails.	
Kind and size of dinkey	Standard locomotive
Length of haul	3 miles
Number of trains	3 of 15 cars each

Note.—The bank was dry and the pit seemed to need no draining. Material was easy to handle, and a much larger dipper could have been used. Four-yd. cars had been employed previous to the 12-yd. cars and it was found that two swings of a 2½-yd. dipper filled these cars completely; seven swings of a 2½-yd. dipper filled the 12-yd. cars completely. Pit crew was composed of rather green men. The runner said he could move up (6 ft.) in 1 or 1½ min. in such a pit with a good crew.

	Per cent.
Actual working	57.5
Spotting cars	...
Changing trains	9.1
Moving shovel	28.3
Shovel taking water	2.2
Miscellaneous delays	2.9
Total time under observation, 396 min.	100.0

Cost of Direct Labor (Loading) Per Day	Standard basis
Runner	$ 5.00
Craneman	3.60
Fireman	2.40
6 pitmen	9.00
1 coal passer	1.50
	$21.50

Number of carloads excavated on day of observation 90
Cubic yards loaded on day of observation, 90 x 12 x 0.83 = 900
Based on the performance observed the cu. yd. loaded per 10-hr. day $= 900 \times \dfrac{600 \text{ min.}}{396\frac{2}{3} \text{ min.}} = 1{,}360$ cu. yd.

$$\frac{\text{Cost of labor per day}}{\text{Number of cu. yd. per day}} = \frac{21.50}{1{,}360} = 1.58 \text{ ct. per cu. yd.}$$

Report No. 13. Shovel No. 666, Inspected July 17, 1909, at Kent, Ohio.

This work was part of that done for correction of line on the W. & L. E. R. R., near Kent, Ohio.

Before cutting in, this shovel, a 70-ton Bucyrus, was moved 1,600 ft. The shovel crew, 16 men, foreman and 1 team were engaged in this work for 8 hr., at a total cost of $34.00, or 2.12 ct. per ft. moved.

	Per cent.
Actual working	37.6
Waiting for cars	21.9
Moving shovel	25.7
Pulling track	13.6
Miscellaneous delays	1.2
Total time under observation, 381 min.	100.0

Cost of Direct Labor (Loading) Per Day	Standard basis
Runner working	$ 5.00
Craneman	3.60
Fireman	2.40
6 pitmen	9.00
	$20.00

Number of cars loaded on day of observation, 189 × 4 yd.
Cubic yards loaded on day of observation, ... 189 x 4 = 756.
Based on performance observed, the cu. yd. loaded per 10-hr. day $= 756 \times \dfrac{600 \text{ min.}}{381 \text{ ft. } 22 \text{ in.}} = 1{,}190.$

$$\frac{\text{Cost of labor per day}}{\text{Number of cu. yd. per day}} = \frac{\$20.00}{1{,}190} = 1.68 \text{ ct. per cu. yd.}$$

Report No. 16. Shovel No. 980, Inspected Aug. 28, 1909, at Chicago, Ill.

This shovel of the 70-ton class was owned by the American Brick Company, and was at one of their yards, about 15 miles

outside of Chicago, employed in digging clay. The boom and dipper handle were of steel and the boom was truss shaped.

Three-yard narrow gauge cars were used, which could be dumped on one side only.

The arrangement shown on the sketch and photographs worked satisfactorily, since with four cars the granulator was well supplied with material. The time for a round trip was obtained several days after the observations were made on the shovel.

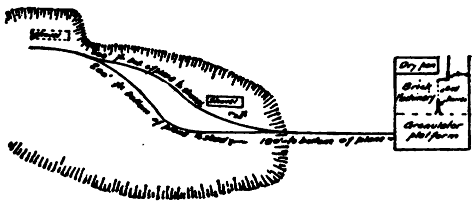


Fig. 41. Arrangement of Tracks and Incline Plane at Brick Plant.

The shovel was then located at the foot of the incline, so that no horses were necessary and only one car was used. One man at the bottom of the plane hooked the cable to the cars. He also assisted in moving forward.

OBSERVATIONS

Capacity of dipper	2½ yd.
Number of cars loaded	166
Cubic yards excavated	498
Coal used	1.3 tons
Number of times moved forward	2
Area of section of face	830 sq. ft.
Height of face	10 ft. to 26½ ft., average 18 ft.

	Per cent.
Actual working	32.8
Waiting for cars	58.4
Moving shovel	1.7
Idle	
Tightening bolts on bull wheel engine	0.2
Firing	0.2
Oiling	1.1
Car off track	4.6
Repairing track	0.7
Miscellaneous delays	
Moving boulder	0.1
Clearing track	0.2
Total time under observation, 471 min.	100.0

	Standard basis
Runner	$ 5.00
Craneman	3.60

	Standard basis
2 pitmen	3.00
1 hooker-on	1.50
2 drivers	3.00
2 horses	3.00
Hoisting engineer	2.40
1 dumpman	1.50
Total cost of labor per day	$23.00
Cost per day per cubic yard	4.62

Dipper performance		Min.	Av.	Max.	No. Obs.
Digging	Time in seconds	5.5	10.7	17	30
Swinging loaded	Time in seconds	3.0	6.6	14	28
Swinging empty	Time in seconds	4.0	5.5	9	25
Falling	Time in seconds	2.0	2.9	4	20
Time to fill and load one dipperful		14.5	25.7	44	

Time for a complete swing

	Minimum	Average	Maximum	No. Obs.
Seconds	19	26.2	31.5	19

Report No. 17. Shovel No. 424, Inspected Sept. 2, 1909, at Riverdale, Ill.

This machine, a 65-ton shovel, was new when the brick company bought it and had been used by them ever since (about eight years) to dig out clay. A chain was used for hoisting, but the swinging was done with a steel cable. The cutting edge of the dipper was a solid plate extending 18 in. beyond the lip and riveted to the latter, being rounded off and drawn out to a sharp edge in front. The face against which the shovel worked was very high (26 ft.) and it frequently caved in, sometimes falling upon the dipper, causing considerable strain on the dipper handle and crane engine.

The clay in the pit was very heavy, but was not blasted before digging.

The engineer did his own firing and the craneman superintended the moving forward. One of the two pitmen saw that the track was not obstructed, threw the switch for the cars, the other looked after the jacks and the pit.

The cars were all provided with 2-hp. motors, to which current at 125 volts was supplied through a third rail in the middle of the tracks. The capacity of the cars was 3.12 cu. yd., but they were heaped full. They dumped on one side only. The top of each car was five feet above the track. They did not move very fast, but their motion was constant and the service was satisfactory. The steepest grade was 5% against the empties, but even here the speed was noticeably reduced, so that it is not likely that cars of such low horse-power would be of use to a

contractor under the usual conditions. Seven horse-power cars were tried on this track, but were found to be too fast and easily became derailed. The cars were run by one man, who controlled switches located at about the center of the system, which was divided into seven circuits, each controlled by a single-pole knife switch, so that the operator could control each individual car at any time and at any place along the line. At the end of each branch, or where a car was switched back on another track, the reverse switch was thrown by an automatic contrivance, which was simply a small steel frame with a bent bar that knocked the reverse lever up as the car passed by. At the end of the line, where the cars were loaded, one of the pitmen knocked down the lever when the car was ready to start, and the switchman, seeing this done from his shed, closed the switch for that circuit. When the cars ran out to the shovel the switchman had to open the circuit when they neared the end; then, just as they struck the bumper, which was part of an old hoisting chain wrapped around one rail, the pitman placed a block under the wheels. The third rail runs to the foot of the incline, where a wire cable is attached, and the cars were drawn up by an electrically operated hoisting engine.

All the switches worked automatically by springs, there being no one to attend to the cars after they passed the switchman and until they arrived at the foot of the incline, where a man attached the cable.

There are two granulators in the mill, but only one was in use so that the shovel was often delayed waiting for the cars to be dumped and returned. When both machines were run, however, there was more work for the shovel, and a fireman was furnished.

Ground up brick powder was used on the rails in place of sand to keep the shovel wheels from slipping when moving up.

OBSERVATIONS

Weight	65 tons
Capacity of dipper	2½ cu. yd.
Height of dinkey tracks above shovel tracks	25 ft.
Number of cars loaded	158
Cubic yards excavated (place measure)	474
Number of times moved forward	3

	Per cent.
Actual working	33.8
Waiting for cars	59.5
Moving shovel	2.3
Idle	
Engineer firing	0.9
Axle box knocked out of car	2.3
Tightening jacks	0.1
Miscellaneous delays	
Clearing track	1.1
Total time under observation, 475 min.	100.0

Runner	$ 5.00
Craneman	3.60
2 pitmen	3.00
1 controllerman	2.60
1 cableman	1.50
1 hoistman	1.50
1 cardumper	1.50
1 watchman	1.50
Total cost of labor per day	$20.20
Cost per cubic yard	4.27

Yearly Repair Cost

Year	Cost
1903	$ 273.20
1904	70.88
1905	138.20
1906	375.12
1907	47.55
1908	116.43
1909	266.86
Total for 6½ years	$1,288.24
To this must be added, for boiler repairs, including labor	200.00

Maximum = $375
Average = 198
Minimum = 48 Not including boiler

Report No. 19. Shovel No. 517 at Buhl, Minn., is of interest in that it reports that the jack blocks for this shovel were slightly different from the ordinary ones. Mr. Butler said that they had been trying different kinds and had found that pyramiding several thin ones was better than the use of large heavy blocks. The ground block in this case was 4 ft. by 6 ft., composed of 3 layers of 2-in. by 10-in. stuff. The top and bottom members run the 6 ft. length of the block. The next block was 3 in. by 3 in. by 4 in. thicker, the next 2 ft. 6 in. by 2 ft. 6 in. by 4 in. and the top block 2 ft. by 2 ft. by 4 in. The jack plate rested on this with a base about 1 ft. square. The plate was free from both block and jack.

Extra large and strong teeth are necessary in this mine because of the nature of the digging. Teeth weighing 460 lb. each are used and these are often bent and broken. One tooth was observed which had been bent over and down until it lay against the lip of the dipper.

Steam Shovel Work in Iron Ore. Very unusual efficiency is shown by the investigation of the work done in the iron ore regions of Michigan and Minnesota. There seem to be the following reasons for this: 1. The work is largely in the nature of a permanent installation, and consequently years of study on one job have developed an efficiency that a contractor is not likely to attain on one comparatively short piece of work with uniform

conditions, or on many jobs with varying conditions; 2. The material is generally quite uniform, and presents month after month and year after year fewer new and strange conditions than does the average run of rock work, therefore the problem is simpler; 3. It appears that the companies operating in this region for some reason are in the habit of studying their unit costs more systematically than the average contractor's organization. Study of these costs invariably leads to more economical work, wherever we have observed them.

The notable feature in ore handling is its great density, involving a much greater amount of power to raise a cubic yard, than in the case of the earths.

The shovel ordinarily employed weighs from 65 to 90 tons, though larger ones are used, and will handle from two to five tons of ore at each swing of its dipper.

Many of the companies use standard gauge equipment entirely and this simplifies their work immensely; for instance, if necessary, the loading track can be broken behind the shovel and the shovel moved back on that track at any time. Generally, however, a standard gauge track is laid keeping within 40 or 60 ft. of it and when the shovel has finished a cut it backs up on this track, which at once becomes the loading track for the next shovel cut.

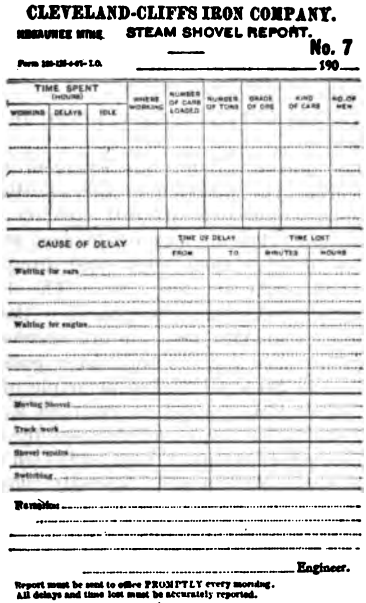
In the stripping, as done in the Sellers' Approach, the teeth on the dipper have to be renewed at least once a week and this is generally done every Sunday. It sometimes becomes necessary to replace a single tooth or perhaps two of them during the week, but each shovel is supposed to use 4 teeth per week and this average holds as a general rule. In ore the teeth are supposed to last a month. They are never broken and seldom bent and all wear down evenly. They wear from the outside or the bottom, as one craneman expressed it, and so keep themselves sharpened. They are allowed to wear down within about 6 in. of the lip and the short blunt teeth thus obtained seem to make no difference in the digging.

The cars used for earth are of the 7-yd. side-dump type. For ore the one most commonly used is the 100,000-lb. pressed steel hopper car.

For stripping, the shovel crew is the usual organization with 4 or 6 pitmen, varying with the nature of the work. The number is generally 4, with 2 extra men to clear track. These two men are called "rock men" and are used in the pit only in case of emergency. When loading ore the pit crew is always 4 and the rock men may number as many as 8. The rock gang varies according to the nature of the ore being loaded. If the ore breaks

out in large pieces it has to be sledged, and if taconite occur this must be removed. On No. 1083 there were 6 rock men in the pit and two in the cars throwing out rock and suspicious-looking ore,

All pieces of rock or taconite too large to lift by hand and too hard to break are thrown by the shovel as far back as possible and left. The pieces that the men can handle are thrown down near the loading track at the foot of the bank to be loaded later.



CLEVELAND-CLIFFS IRON COMPANY.

NEGAUNEE MINE. **STEAM SHOVEL REPORT.**

No. 7

Form [illegible] ______ 190__

TIME SPENT (HOURS)			WHERE WORKING	NUMBER OF CARS LOADED	NUMBER OF TONS	GRADE OF ORE	KIND OF CARS	NO. OF MEN
WORKING	DELAYS	IDLE						

CAUSE OF DELAY	TIME OF DELAY		TIME LOST	
	FROM	TO	MINUTES	HOURS
Waiting for cars				
Waiting for engine				
Moving Shovel				
Track work				
Shovel repairs				
Switching				

Remarks ______

______ Engineer.

Report must be sent to office PROMPTLY every morning.
All delays and time lost must be accurately reported.

Fig. 42. Report Form for Shovel Work.

This loading is done as follows: Several dump cars are left at each shovel. When a train arrives to be loaded these cars are coupled to the front end of it and pushed along with the train. When loaded, the train spots the dump cars at the shovel and pulls out, leaving them there. The shovel then picks up what it can of the pile of rock by the loading track and what it cannot get hold of readily is thrown into the dipper by hand. This is then dumped into the cars. When the next ore train arrives it simply pushes the dump cars out of the way, loads and again spots the cars and pulls out. When rock is loaded into the

cars with the ore there is sometimes a slight delay when the two workmen on the cars jump down to pick it out. If there is much of it, or if it has to be sledged, the loading must be stopped while the men finish their work and get out of the way. In such cases the full dipper is held just clear of the car, while the men move aside, immediately after which the swing is completed. This delay does not amount to much for each swing, since it is only a few seconds long, but if much rock should be loaded with the ore the delay might amount to several dippers full per day.

Work is seldom stopped by rain and it may be said that during the shipping season the loading of ore is never interrupted because of the weather.

Report No. 24. Shovel 1127, Inspected Sept. 10 and 11, 1909, at Ironwood, Mich.

Material. This shovel, a 70C, was engaged in hematite iron ore stock pile work. The function of the so-called "stock pile" is to keep the mine running at its full capacity the year round.

General Conditions. During the navigation season the mined ore is brought up in skips from below, and dumped into the two pockets and thence into the ore cars. The loaded cars are then hauled to the docks and dumped into the pockets there. From here it runs by gravity into the ore vessels.

When navigation closes and it is no longer possible to ship ore, work is begun on the stock pile. The principle of construction is much like that of an immense fill on railroad work. The ore is mined and brought up in skips and dumped into the pockets as usual. From here it is dropped into cars, which are run out upon the trestle work and dumped. Usually planking is laid on the ground to receive the ore. Stock piles, of course, vary in size according to the output of the mine. This one was exceptionally large, being some 900 ft. in length and almost 30 ft. high. An important feature of a large stock pile is that it permits the use of a long train and materially reduces the lost time due to switching. The ore thus stored in winter is loaded into cars during the navigation season by steam shovels.

OBSERVATIONS

Type shovel ....Bucyrus 70-ton
Size of bucket ....2½ yd., 4.27 tons average
Length of shift ....10 hr.
Coal used ....About 2½ tons in 10 hr.
Oil used ....Black, 0.55 gallons; cylinder, 0.89 gallon; engine, 0.66 gallon, in 10 hr.
Water used ....4,500 gallons in 10 hr.
Boiler cleaned once in four weeks, on Sunday.
Kind of track ....45-lb., standard gauge
American Car and Foundry Co. steel ore cars, capacity 40 tons, but carrying 47 tons each.
Kind and size of dinkey: Fairly heavy switch engine is used. One engine for spotting.

DEDUCTIONS FROM OFFICE RECORD OF SHOVEL

No. days worked	23
Total tons output	69,560
Tons per day	3,024
No. tons per dipper	4.27
No. dippers per car	11
Average No. of cars of 47 tons loaded per day	63.4

Average of 23 days	Per cent.
Actual working	53.1
Changing trains	15.4
Moving shovel	11.5
Miscellaneous delays	20.0
Total time under observation, 600 min.	100.0

Cost of Direct Labor (Loading) per Day	Standard basis
Engineer	$ 5.00
Craneman	3.60
Fireman	2.40
6 pitmen	9.00
	$20.00

Tons excavated per day (average 23 days), 3,024. Two tons per yard, 1,512 cu. yd. per day.

Cost of labor per day, $20.00.

Cost of labor per day, per cu. yd. (load only) $\frac{\$20.00}{1,512} = 1.32$ ct. per cu. yd.


NEWPORT MINING COMPANY.
STEAM SHOVEL REPORT.

SHAFT.............. ....

GRADE.............. ....190....

NO. MEN..............

TIME	CARS S	CARS 6	TONS	DELAYS Repairing	Switching	Cars	Move Shovel	Miscellaneous
7 to 8								
8 to 9								
9 to 10								
10 to 11								
11 to 12								
12 to 1								
1 to 2								
2 to 3								
3 to 4								
4 to 5								
5 to 6								
6 to 7								
7 to 8								
8 to 9								
TOTAL								

Condition of Stockpile..............

REMARKS:..............

..............ENGINEER.

Fig. 43. Report Form for Shovel Work.

Report No. 34. Shovel No. 1097, Inspected July 26 and 28, 1909, near Johnsonburg, N. J. The shovel was working in shale and limestone on Section No. 5 of the D. L. & W. cut-off.

OBSERVATIONS — GENERAL

Weight	70 tons
Capacity of dipper	2½ cu. yd.
Capacity of cars, water measure	4.00 cu. yd.
Number of cars in train	9 and 10
Length of haul	7,500 ft.
Length of runaround, 1st day, 3.37 miles; 2nd day, 3.35 miles	
Weight of dinkeys	18 tons
Style of car, side dump on one side only.	
Gauge of dinkey tracks	Narrow
Number of trains	7
Average time for round trip	45 min.
Maximum grades for loads	4.0%
Complete trains for grades? Yes.	
Time traveling to dump	18.8 min.
Time traveling from dump to shovel	17.7 min.
Time to dump cars	4.9 min.

OBSERVATIONS — FIRST DAY

Number of cars loaded	296
Cubic yards, place measure	1,065 yd.
Total distance moved forward during day	79½ ft.
Average time for one move	6.5 min.
Average distance moved forward each time	6½ ft.
Minutes per working day less time for accidental delays	518
Area of section of face	210 sq. ft.
Average height of face	4½ ft.
Coal used	2.3 tons

	Per cent.
Actual working	53.4
Spotting cars	0.3
Waiting for cars	22.0
Moving shovel	15.3
Miscellaneous delays	(9.0)
Clearing away	8.4
Breaking bank	0.2
Placing car on track	0.4
Total time under observation, 518 min.	100.0

Cost of Direct Labor (Loading) per Day	Standard basis
Runner	$ 5.00
Craneman	3.60
Fireman	2.40
8 pitmen	12.00
	$23.00

Cubic yards loaded on first day of observation 1,065
Based on the above performance the cu. yd. loaded per day

$$\text{of 10 hr.} = 1{,}065 \times \frac{600}{518} = 1{,}235$$

$$\frac{\text{Cost of direct labor per day}}{\text{Number of cu. yd. per day}} = \frac{\$23.00}{1{,}235} = 1.86 \text{ ct. per cu. yd.}$$

Cost of Moving Back	Standard basis
Runner for 1.59 days @ $5	$ 7.95
Craneman for 1.59 days @ $3.60	5.72
Fireman for 1.59 days @ $2.40	3.82
14 laborers for 17½ hr. @ $0.15	36.75
2 drivers for 17½ hr. @ $0.15	5.25
2 horses for 1.59 days @ $1.50	4.77
4 pipe fitters for 1.59 days @ $2	12.72
Coal; 2 tons @ $3.50	7.00
Oil and waste	1.00
Shifting track	
10 laborers for 17½ days @ $0.15	26.25
1 foreman for 1.59 days @ $2	3.18
Tearing down trestle	
6 laborers for 5½ hr. ½ $0.15	4.95
2 horses for ½ day @ $1.50	1.50
Coal, 2 tons, @ $3.50	7.00
Oil and waste	1.00
Total cost to move back	$128.86

Total distance moved	820 ft.
Total time actually moving	1 day
Total time idle	1.59
Number of men employed	60*
Cost per ft. moved	15.71 ct.
Cost per ft. per man	.262 ct.

* Includes pulling down trestle, shifting track, and one horse equal to four men.

CARS LOADED DURING SIX MONTHS

	Total for month	Daily average
February, 1909	4,388	183
March	5,248	202
April	5,096	204
May	6,241	250
June	5,622	216
July, 1 to 24 inc.	3,275	155

HAULING RECORDS — DINKEY TRAINS

Minimum rate in ft. per min.	178.4
Average " " " " "	317¼
Maximum " " " " "	440.1
Minimum time for trip	45 min.
Average " " "	61.7 min.
Maximum " " "	95 min.

Report No. 35. Shovel No. 795, Inspected Aug. 10, 1909, near Columbia, N. J.

The cars were built by the Western Wheel Scraper Company. Some of them dumped on both sides and some on one side only. They measured 110 x 83 x 19 in. and were 5 ft. 6 in. above their tracks. When loaded with stone they averaged about 2½ yd. Three 18-ton Vulcan dinkeys were used at each shovel, with an extra one which during inspection held trains back in descending a steep grade ending in a sharp curve. In order to dump from

the trestle it was necessary for the dinkey to run around the train, as they always pulled, instead of pushing, the cars when running loaded. This took from two to three minutes. Then, after dumping, it was necessary for the dinkey to switch back again, but as this was a flying switch very little time was lost. Under the observed conditions it was necessary for the dinkey to uncouple while the car next to it was loaded. The reason for such an arrangement appears to be in the fact that the cars ride better when being hauled than when pushed, and in this connection it should be remarked that the number of derailed cars was very small. The dinkeys maintained a steady pace that was not as fast as on some other jobs, but which made better time in the end because the chances for a car to jump were diminished.

RATE OF MOVING TRAINS

Distance	12,600 ft.
Running time	15 min.
Rate	840 ft. per. min.
Delays	54½ min.
Total time for round trip	69½ min.

Cost to Move Shovel (65-ton) from Siding to Work	Standard basis
Runner, 40 hr. @ $0.50	$ 20.00
Craneman, 40 hr. @ $0.36	14.40
Fireman, 40 hr. @ $0.24	9.60
Watchman, 40 hr. @ $0.15	6.00
Fireman, 40 hr. @ $0.20	8.00
Laborers, 745 hr. @ $0.15	111.75
Team — ties, 40 hr. @ $0.30	12.00
Team — coal, 20 hr. @ $0.30	6.00
Coal and oil	4.50
	$192.25

RATE OF MOVING TRAINS

(Shovel 350, Report No. 42)

Distance	16,000 ft.
Running time	28 min.
Rate	604.8 ft. per min.
Delays	34 min.
Total time for round trip	62 min.

Hints on Steam Shovel Work. The following are taken from the many suggestions on Steam Shovel work given in the Handbook on that subject which is published by the Bucyrus Co.

Handling Trench Sheeting Under a Shovel. Report No. 9 relates to a 70-ton shovel used in digging a sewer trench.

It was new and of the latest design. Its distinguishing features were the location of the operating levers, those being placed about 5 ft. outside the shovel housing; the long dipper handle; and the support upon which the shovel rested. The operating levers were placed outside of the shovel house so that the operator might

have an unobstructed view of the bottom of the trench. The dipper handle was 54 ft. long so that it could reach into the deep trench which was 26 x 16 ft. Both it and the boom were of wood and were steel plated.

The shovel crew consisted of engineer, craneman, fireman and seven rollermen. There were also employed six trimmers, six bracers and one foreman following the digging.

To move the shovel backward or forward, a cable, hauled on by the main engines, was led out to a "dead man." By actual timing the shovel was moved back 416 ft. in 3½ hr.

Two days were spent in observing this shovel. On the first day the top soil to a depth of 10 ft. was removed and on the second day the remaining depth of 26 ft. was taken out. As the shovel excavated the trimmers followed it, trimming down the sides for

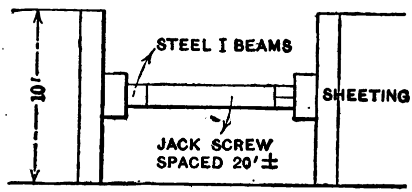


Fig. 44. Method of Bracing Trench.

the bracers who followed with the sheeting. Two I-beams about 50 ft. long are placed as shown in the sketch, so that when the next bench is taken out and it is necessary to draw the braces the I-beams hold the sheeting and the shovel works between the jack screws. When the shovel moves forward the jack screws are slightly loosened and the I-beams are attached to the shovel and hauled forward with it, the wooden bracing being placed behind the I-beams. This being a new shovel there had been no repairs.

Handling Shovel Track on Stock Pile Work. The stock piles are built to considerable height and are apt to cave in and cause trouble when undercut by the shovel.

In view of this fact the method of keeping a continuous track behind the shovel was used on shovel 1074, report No. 27, so that it could move back at a moment's notice. This was done by having enough extra 6-ft. sections of rail which could be left behind in place until the shovel had moved forward far enough for a regular full length rail section to be put in by the track gang. When the shovel became buried, the first thing to do was to clear the jacks, the next to move back, and the last to shovel up the fallen material and then move ahead until another slide occurred,

For shovel 1083, report no. 28. Both the shovel and loading track were standard gauge, laid with standard ties and 50 or 60-lb. rails. The shovel was moved forward on 6-ft. sections with the usual plate connections and bridles, but as soon as it had moved about fifty feet, a standard track, which was laid in the rear of the shovel, was extended for a rail length and was so carried along directly behind the shovel. When the shovel was ready to move back this track was connected with the shovel track and the shovel had a continuous standard track to move on. This track then became the loading track for the next cut, and that previously used as a loading track was torn up.

In one case in order to cut in more rapidly than is possible with the ordinary 5-ft. rail sections, small 1-ft. sections were used between the 5-ft. rail sections to make the shovel track more flexible.

Taking Down Boom and Dipper. Shovel No. 700 was being dismantled preparatory to taking boom and dipper into the shop. The process is as follows: An empty flat car is placed on the track directly ahead of the shovel. The dipper is then thrust out as far as possible by the crane engine and allowed to rest on the far end of the flat car and on the left hand side. The hoisting chain is then slackened and the bight pulled down between the two sides of the dipper handle. A stout rod is then thrust in between this bight and the underside of the dipper handle near its upper end. After disengaging dipper handle from the rack pinions, it is slowly lowered to the flat car by paying out the hoisting chain. The hoisting chain is then released from the padlock and wound up on the drum. The end of the hoisting chain is then pulled out and passed over a pulley suspended from the A frame; thence up the boom and around a sheave at its top and thence back to the top of the A frame to one leg of which it is securely fastened. The boom is then raised slightly by the hoisting engines until the strain is removed from the tie rods which connect the upper end of the boom and the top of the A frame. These tie rods are now uncoupled from the top of the A frame and gradually eased down onto the car. The method used for thus lowering the tie rods is as follows: A stick of round timber some 4 in. in diameter and 4 ft. long, to which a pulley is lashed, is jammed into the head of the A frame. Through this block a rope passes from below and is secured to the upper end of the tie rods, one at a time. A workman holds the lower end of the rope, and so the tie rods are let down gently.

The boom itself is now supported only by the hoisting chain and this is now slacked away until boom rests on the right hand

side of the flat car. The hoisting chain is then disengaged and wound up on the drum. The shovel then backs up a little, thereby removing the lower end of the boom from its socket. A timber is then placed between the front of the shovel proper and the end of the boom and the shovel moved forward until the boom is pushed over the flat car far enough to be clear of the end. The only thing remaining to be done is to take down the block suspended from the top of the A frame and place it on the car with the boom and dipper.

At one job examined, report No. 30, the contractor had three machines of exactly the same type which enabled him to keep a large number of spare parts on hand. These machines had jacks that could be swung toward the shovel so that in passing

Fig. 45. View Showing Device for Turning Cars.

narrow places it was only necessary to loosen the brace and swing the jacks to one side. This feature proved to be a great help.

The method employed here was similar to that at Shovel No. 893 (see report No. 6) and consisted in laying standard length rails for a considerable distance preparatory to moving. When the inspectors arrived the rails had all been laid and had been run into the dinkey tracks, which had been widened to a standard gauge for a distance of about 500 ft. This was done by simply taking the outside spikes out of one rail and shifting it over, leaving in the inside spikes to be used when the track should be shifted back again to narrow gauge.

At another shovel visited, report No. 31, a registering clock was used to keep the time of arrival and departure of the men. From these cards the payroll was made up, and to save time the extensions were made weekly on the cards themselves. The time-keeper went over the job during the day to check up the men.

Another shovel was fitted with a small air compressor and tank. The compressor was located in the rear left-hand corner of the shovel and took up a space about 6 ft. high by 1 ft. in diameter.

Moving Shovels. The method employed for moving shovels 1096 and 1097 was somewhat different from others that had been observed. Two horses and sixteen men were used, eight lengths of 30-ft. 60-lb. rail and about one hundred ties, besides bridles, spikes, etc. The shovel was moved back two rail lengths at a time, the forward rails and ties being taken up and hauled by the horses to the rear, where the laborers lifted them into place.


HYDE-McFARLIN-BURKE COMPANY
DAILY TIME REPORT

DISTRIBUTE ENTIRE LABOR FOR THE DAY UNDER HEADS NOTED HEREON

Fig. 46. Form for Reporting Steam Shovel Work.

Two men stayed in front to unbolt as soon as the shovels moved back, two others took up the ties as the horses hauled away the rails. One man was required to follow the chain used for hauling the ties to see that it did not get caught in an obstruction, it being apparently too heavy to throw over a horse's back. Four men were kept in the rear to lay the ties as they came in, and the remaining men went where instructed. Eight men were required to lift each rail into place. The bridles were carried forward by the men, or else laid among the ties that the horse drew. There were enough extra ties to support the first rails that were brought, and these were laid while the shovel was moving, so that there was no delay when the rails were taken up.

Cost of Moving Back	Standard basis
Runner for 1.25 days @ $5	$ 6.25
Craneman for 1.25 days @ $3.60	4.50
Fireman for 1.25 days @ $2.40	3.00
14 laborers for 13½ hr. @ $0.15	28.35
2 drivers for 13½ hr. @ $0.15	4.05
2 horses for 1.23 days @ $1.50	3.69
4 pipe fitters for 1.25 days @ $2	10.00
Coal, 2 tons, @ $3.50	7.00
Oil and waste	1.00
Shifting track:	
5 laborers for 13½ hr. @ $0.15	10.12
9 laborers for 11 hr. @ $0.15	14.85
1 foreman for 1.25 days @ $2	2.50
Total cost to move back	$95.31

Total distance moved	1,063 ft.
Total time required	1.25 days
Total number of employed	46 *
Cost per ft. moved	9.0 ct.
Cost per ft. per man	0.196 ct.

* Includes shifting track; one horse taken as equivalent of four men.

Throwing Track. At shovel 1106, report No. 43, the throwing of the loading track was very difficult because of the roughness of the material which was left in the shovel pit and because of the large number of boulders which the shovel could not handle. Much delay was caused on account of having to break up boulders to permit of lifting full sections of track over them, and considerable time was lost for both track gang and shovel

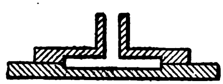


Fig. 47. Arrangement of Plates for Holding Rail.

crew by blasting. The blast itself took no longer than usual, but because of the uneven character of the material the charge could not always be properly regulated, with the result that very often considerable damage was done to the track and to the shovel by flying material. The track foreman said that with a crew of twenty men it would take 2 hours' continuous work to throw 800 ft. of track. Most of the track had been thrown before the shovel moved back. When the shovel did move back over this part the rails were placed over the track which had been thrown. Moving back was also interrupted, due to blasts. The foreman said that with an average force of twenty-two men the shovel could be moved back the 800 ft. in 4 hours' continuous work.

Regular size of tie 6 in. x 8 in. were used under this shovel but

to each 6-ft. length of rail there was one 8 x 10-in. tie. On this tie plates were fastened, at the proper distance from each end, each with two angles attached.

Upon moving up each time the 6-ft. rail section could be readily slipped into the groove, as shown in sketch, and pins slipped into holes to secure it.

Directions for Moving Shovel. In order to systematize the various operations in moving a steam shovel and thus reduce the cost to a minimum, the order in which these movements should be made is given.

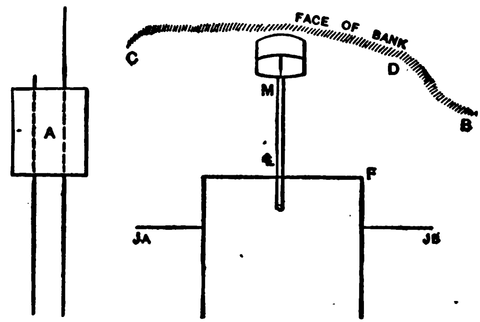


Fig. 48. Diagram of Shovel and Track.

(1) Just before moving, the last dipperful will be taken from B. As this dipper is being filled, runner gives one whistle signal to the pit gang (six men in pit). Two men go to JA and two to JB, and one man goes out to F on the rail clamp and one to H on the rail clamp.

(2) As soon as the dipper has swung to the left of the center (M) JB is loose, and one of the men there runs up the screw.

(3) One man at JA puts his pole over the jack and gets ready to raise his jack block. Meanwhile the dipper has dumped at A.

(4) Other man at JB now raises his jack block and is ready to move.

(5) Dipper swings to the right far enough past M to take the weight off of JA, which is immediately screwed up and the block raised.

(6) While runner is throwing in his moving clutch, one man at F is knocking loose rail clamp, and one man from JA and one from JB pick up the chock and carry it forward to its new position.

(7) Runner now moves shovel ahead; H knocks the clamp loose. F is meanwhile putting his clamp on in the new position.

(8) As soon as the shovel strikes the front chock, H puts his clamp on. The bucket is in the center position for this movement.

(9) The jackmen JA and JB immediately screw down their jacks, and the first man to get his jack down gives signal to runner, who takes first bucketful on his side. This enables man on either side to get his jack well screwed down before bucket crosses center line again, working away at full speed.

Shovel now works away even if a little out of level. It can be leveled up by runner telling JA or JB to loosen a little, the opposite man screwing down on the next half swing.

Cost of Moving Steam Shovels. In *Engineering News*, May 21, 1903, the author published data on the cost of constructing

part of the P., C. & W. R. R. in a mountainous portion of Ohio. The cost of moving large and small steam shovels was as follows:

A 65-ton Bucyrus shovel was moved a distance of 1½ miles. One mile was over a rough road and one-half mile across a field having a slope of 15°. The work occupied 8 days, and cost as follows:

Steam shovel crew	$160
Foreman at $3.50	28
8 men at $1.50	96
1 team at $4	32
Total at $210 per mile	$316

This same shovel was also moved 6 miles in 30 days, and again ¼ mile down one hill, across a valley to another hill in 23 days, at a cost of about $40 per day.

A 35-ton Vulcan traction shovel was moved over 18 miles of rough road, the last mile being up a steep hill and over field. The time occupied was 18 days, and the cost about $35 per day and $35 per mile.

According to Mr. C. T. Montague, in *Engineering and Contracting*, Apr. 23, 1913, a 70-ton Bucyrus steam shovel was moved 24.2 miles in 8 days over country roads and fields during March when the average temperature was 10° F. The regular wheels of the machine were removed and replaced with trucks of the ordinary house-moving type, consisting of three units of four wheels, each mounted on false bolsters. The shovel was drawn by a 32-hp. steam tractor and a 25-hp. tractor, with a 5-ton motor truck to help out on the starts.

Many deep ravines and sharp turns were encountered but no difficulty was experienced except from the scarcity of water. Only 4 laborers were employed. The cost of moving was $48 per mile.

Victor Windett in *Proceedings of the Western Society of Engineers*, Jan. 7, 1911, gives the following: The cost of moving a shovel under its own steam on rails from a railroad-siding to the site of the work in Chicago, for a haul of something over a mile, was at the rate of 6.5 ct. per lin. ft.

In New Orleans a 25-ton shovel was moved 13,000 ft. at the rate of 260 ft. per hr. The work required 5 days' time, as follows:

Removing and resetting crane	$100
Labor, teams, coal and water	175
Cutting electric wires and general expense	75
Total	$350
Cost per lin. ft. to move	2.8 ct.

A team was used to drag ahead the pieces of track over which the shovel had moved.

Cost of Moving a Shovel by Motor Trucking. Everett N. Bryan in *Engineering Record*, June 17, 1916, gives the following record of cost of moving a 60-ton Marion shovel 32 miles, from La Grange to Modesto, Calif. The entire time was 61 days, using a small crew of men. This time could have been cut in half with a larger crew. Before moving, the shovel stood in a pit 50 ft. deep. A road 750 ft. long had to be graded out of the pit, 200 ft. of which was up an 18% grade. The shovel pulled up this grade with its own power using a wire rope tackle. Then it was dismantled and hauled in nine loads by a 5-ton motor truck using a trailer.

The heaviest of load was 10.5 tons, consisting of the main frame with decking attached, 10 x 35 ft.

The cost was as follows:

Dismantling shovel	$ 71.10
Reassembling shovel	194.45
Lumber and tool rental	50.00
" " " haulage	46.40
Breakages	20.00
Grading 750 ft. of road	56.62
Loading assistance	34.94
Unloading assistance	11.40
Total	$ 484.91
Moving shovel 750 ft. out of pit	218.18
Total	$ 703.09
Moving shovel 300 ft. across bridge	37.76
Hauling shovel 32 miles	441.76
Grand total	$1,182.61

The items of loading and unloading assistance relate to wages paid to others than the motor truck driver and his helper while loading and unloading.

The item of moving across a bridge relates to hauling some of the heavy parts on wagons by cable across a light bridge.

Cost of Railway Work. *Engineering and Contracting*, May 30, 1906, gives the following:

In 1895 considerable steam shovel work was done by the Ann Arbor R. R. in the betterment of its grade and line.

The railroad was a single track line upon which it was necessary to keep both freight and passenger trains moving without delay, and some of the work was made more expensive by the fact that from 18 to 28 trains per day had to be contended with. A portion of the work was ballasting, the haul from the gravel pits ranging from 10 to 50 miles. On grade reductions, the haul

ranged from one to four miles. The steam shovels used were track shovels, with 1¼ cu. yd. dipper. Shovels Nos. 1 and 2 were the Bucyrus steam shovels, and were new; shovels Nos. 3 and 4 were Marion steam shovels. The cost figures cover the cost of the loading, transporting, unloading of material and placing it under the track, but make no allowance for rental of plant, locomotive or cars, or per cent. for deterioration of plant.

The rates of labor the season of 1895 were about as follows: Laborers, $1.15 per day; track foremen, $65 per month; work train conductor, $0.25 per hr.; brakemen, $0.17½ per hr.; shovel enginemen, $100 per month and ½ ct. per yd. bonus on all material moved above a 750 yd. per day average.

In sand the cost ranged from 7 to 17 ct. per cu. yd., the average being about 10 ct. In clay the range was 10 to 18 ct., the average being 14 ct.

Cost of Railway Grading. In *Engineering News*, Dec. 31, 1903, D. J. Hauer gives some data on steam shovel work, a portion of which we have abstracted.

The work was during November, 1901, and was the best done in 1½ years by three shovels in North Carolina. These shovels were employed in regrading a railroad track (see Fig. 49), the cut being 1,200 ft. long. The earth to the right of the old track was first excavated to the grade of that track, the shovel loading

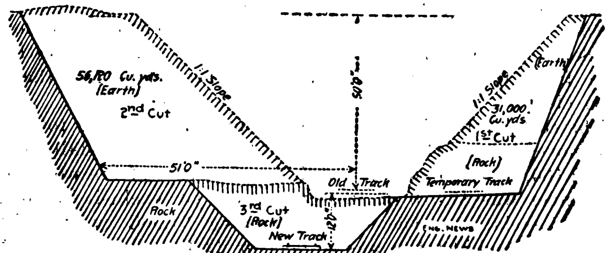


Fig. 49. Cross-Section of Railway Cutting.

into cars on the old track. The solid rock made progress slow, 29,800 cu. yd. of earth and 1,200 cu. yd. of rock being excavated between Sept. 5 and Oct. 31, working day shifts only, except during the last week when two night shifts were worked. During November, day and night shifts of 12 hr. each were worked, the shovel excavating at the left of the main track and using the old track as a loading track.

The material could be classed as average earth, being red clay

and mica. The bank was shot with powder. The width of shovel cut from center of loading track at the widest point was 51 ft.; the minimum width was 35 ft. The height of the breast was 40 ft.

The shovel used was a 65-ton Bucyrus, equipped with a $2\frac{1}{2}$-yd. dipper. A dynamo furnished current for electric light for night work at times. The boiler also furnished steam for a $3\frac{5}{8}$-in. rock drill and a 4-in. steam siphon and $1\frac{1}{2}$-in. jet for pumping. Gasoline lamps were used on the dumps. The shovel had a clear lift of 17 ft., cut 27 ft. from its center and dumped 24 ft.

Two trains of 15 cars each, drawn by 16-in. cylinder locomotives served the shovel. The cars used were Kilbourne & Jacobs, 6-yd., two-way, dump cars; six cars in each train being equipped with brakes. The cars were of 6 cu. yd. water measure capacity, the actual contents as measured in place being 5 cu. yd.

The dumping gangs consisted of 1 foreman and 20 men on one dump 1 mile distant, and 1 foreman and 12 laborers on a temporary trestle dump 2.5 miles distant in the other direction. The former dump was used only during the day time and the latter day and night. A temporary trestle was constructed with bents at 14-ft. centers. The mud blocks, sills, posts and caps were of round timber, the braces of 3 x 8-in. sawed pine, and the stringers of 10 x 12-in. sawed pine. The stringers were used again. This trestle cost 2 ct. per cu. yd. of embankment.

Some delay was caused by the necessity of clearing the loading track for 20 to 30 regular trains per day. Mr. Hauer estimated that fully 40% more work could have been done had the track been clear at all times.

The cost of the plant used was about $27,000. The total yardage moved during the month was 56,120 cu. yd.; the daily average was 2,160, or 1,080 cu. yd. per shift. The cost of the work during November was $7,070 or 12.6 ct. per cu. yd. exclusive of interest and depreciation. The cost of moving 31,000 cu. yd. during September and October was $7,000, or 22.6 ct. per cu. yd.

The rails, ties, switches, and track fastenings were furnished to the contractor by the railroad company, the parts lost and consumed being paid for at market prices.

The cost per month was as follows:

1 engineer in charge	$ 150
1 bookkeeper	65
2 clerks	85
2 telegraph operators board	30
1 watchman	35
2 cooks and 2 helpers	165
1 superintendent	140
1 night superintendent	90
Total general	$ 760

2 shovel enginemen	$ 280
2 cranemen	180
2 shovel firemen at $2.25 per day	59
4 pitmen at $1.25	130
6 pitmen at $1	156
4 blasters at $4.25	111
120 kegs of black powder at $1.25	150
Dynamite, exploders, etc.	65
Total loading force	$1,131
4 locomotive enginemen	$ 360
4 firemen	160
4 conductors	300
8 flagmen at	208
1 switchman at $1	26
1 car oiler at $1	26
Total handling forces	$1,080
1 inspector	$ 40
1 day dump foreman at $3	78
20 day dump laborers at $1	520
1 day and night dump foreman at $3	130
24 day and night dump laborers at $1	624
Total dumping forces	$1,392
1 fireman at $3	$ 78
10 laborers at $1	260
Total track force	$ 338
1 foreman at $2	$ 52
10 laborers at $1	260
1 blacksmith at $3	78
1 blacksmith helper at $1.25	32
3 bays at 75 ct.	59
Total miscellaneous force	$ 481
Oil, gear shield, waste, packing	$ 110
Torpedoes, fuses, etc.	13
262 tons coal at $3.25	851
Repairs to shovel, engines, and cars	285
Trestle (36,000 cu. yd. at 1¾ ct.)	630
Grand total, 56,120 cu. yd. at 12.6 ct.	$7,071

Cost of Filling a Trestle. *Engineering and Contracting*, May 9, 1906, gives the following:

Henry H. Carter gives costs of steam shovel work, begun March 13, 1884, near Boston. The material excavated was fine gravel and sand which was used to fill in a trestle 1,700 ft. long across a lake. The cost of the trestle is not included in the following record, but the cost of laying track to the trestle and of laying a double track on the ties already on the trestle is included.

All told there were 6,700 ft. of single track, laid with 35-lb. rails. The gravel pit was located 3,700 ft. from the middle of the trestle, making the haul average ¾ mile.

The gravel was measured in the pit before loading, and the total amount moved was 59,010 cu. yd. It was found that 1 cu. yd., measured in the cut, or pit, made 1.16 cu. yd. measured in the cars.

The contractor's plant consisted of a steam shovel, two locomotives, 14 dump cars, each holding 2½ cu. yd. car measure, and 16 dump cars holding 1.85 cu. yd. each. For a time a small shovel was used, and its average output was 300 cu. yd. a day, including the days consumed in setting up and shifting plant. However, most of the work was done with a large shovel which averaged 582 cu. yd. per day, including setting up and shifting time.

	Ct. per cu. yd.
Loading ($4,521, or 7.6 ct. per cu. yd.)	
Foreman, 100 days @ $4	0.7
Engineman, 122 days @ $4	0.8
Craneman, 122 days @ $3.50	0.7
Fireman, 123 days @ $1.75	0.3
Laborers, 574 days @ $1.50	1.5
Rent of small shovel, 51 days @ $9	0.8
Rent of large shovel, 75 days @ $13	1.6
Repairs on small shovel	0.2
75 tons of coal for shovels @ $6	0.8
Oil and waste for shovels	0.2
Hauling ($3,639, or 6.2 ct. per cu. yd.)	
Foreman, 10 days at $4	0.1
Engine drivers, 229 days @ $2.50	1.0
Firemen, 216 days @ $1.75	0.6
Brakeman, 105 days @ $1.50	0.3
Icecutter, 15 days @ $1.50	0.0
Rent of 2 locomotives and trains, 235 days @ $7	2.8
120 tons of coal @ $6	1.2
Oil and waste	0.2
Trackwork ($1,492, or 2.5 ct. per cu. yd.,	
Foreman, 10 days @ $4	0.1
Foreman, 95 days @ $2	0.3
Blacksmith, 125 days @ $2	0.4
Laborers, 638 days @ $1.50	1.6
Loss of tools	0.1
Dumping ($799, or 1.3 ct. per cu. yd.)	
Foreman, 82 days @ $2	0.1
Laborers, 490 days @ $1.50	1.2
Miscellaneous ($3,420, or 5.8 ct. per cu. yd.)	
Superintendent, 60 days @ $6	0.6
Foreman, 12 days @ $4	0.1
Engineman, 10 days @ $4	0.1
Craneman, 10 days at $4	0.1
Blacksmith, 128 days @ $2.50	0.5
Laborers, 105 days @ $1.50	0.2
5 tons of coal @ $6	0.0
Blacksmith shop	0.2
Transportation of plant	2.6
Loss of tools and interest on value	0.3
Loss on rails, ties, etc.	0.8
Blacksmith supplies	0.3
Grand total	23.4

Summarizing, we have:	Ct. per cu. yd.
Labor, loading	4.0
Rental of shovels, and repairs	2.6
Coal, ¾ ton per day per shovel	0.8
Oil and waste for shovels	0.2
Labor, hauling	2.0
Rental of locomotives and train	2.8
Coal, (½ ton per day per locomotive)	1.2
Oil and waste for locomotives	0.2
Labor, tracklaying, 1¼ miles	2.5
Labor, dumping	1.3
Labor, installing shovels, etc.	0.5
Blacksmithing	0.5
Blacksmith shop	0.2
Blacksmith supplies	0.3
Transportation of plant	2.6
Depreciation of small tools, rails and ties	1.1
General superintendence	0.6
Total	23.4

Cost on Railway Construction. S. T. Neely, Assistant Engineer, Southern Ry., in *Engineerng News*, Aug. 9, 1906, gives the cost of grade reduction work as follows:

Cost of Equipment:	
1 65-ton shovel	$10,000
3 engines at $2,200	6,600
20-12-yd. dump cars	14,000
1 Jordan spreader	2,400
Extra parts	1,000
Tools (jacks, shovels, bars, etc.)	1,000
Total	$35,000
Annual Charges:	
Interest at 6%	$ 2,100
Renewals in 5 years	7,000
Total per year	$ 9,100
Total per day	$ 25
Daily Operating Cost per Working Day:	
2 foremen at $3.75	$ 7.50
2 timekeepers at $2.35	4.70
1 shovelman at $5	5.00
1 craneman at $2.50	2.50
1 fireman at $2.25	2.25
1 watchman at $2.25	2.25
6 pitmen at $2	12.00
30 dump track raises at $1.75	52.50
13 track men at $1.75	22.75
3 locomotive men at $3.50	10.50
3 firemen at $2	6.00
3 brakemen at $2.50	7.50
1 conductor at $4	4.00
3 flagmen at $2	6.00
1 car repairer at $2	2.00
1 blacksmith at $3.50	3.50
1 blacksmith helper at $2	2.00
1 superintendent at $5	5.00
1 telegraph operator at $2	2.00
Total daily pay roll	$159.95

Interest and renewal	$ 25.00
2 tons coal for 3 engines at $2	12.00
2 tons coal for shovel at $2	4.00
Waste and oil at 75 ct. per machine	3.00
10,000 gal. water at 50 ct. per 1,000 gal.	5.00
Total fuel and water	$ 49.00
Total per working day	$209.00
Non-Working Day Expense:	
2 foremen at $3.75	$ 7.50
2 timekeepers at $2.35	4.70
1 shovel engineer at $5	5.00
1 craneman at $2.50	2.50
1 fireman at $2.25	2.25
1 watchman at $2.25	2.25
3 locomotive engineers at $3.50	10.50
3 firemen at $2	6.00
1 conductor at $4	4.00
1 superintendent at $5	5.00
1 telegraph operator at $2	2.00
Labor of ditching, etc., 20 hr. at 0.175	3.50
	$56.20
Interest and renewals	25.00
Fuel and oil for 1 engine	5.00
Total non-working day expense	$86.20
Cost per month:	
20 working days	$4,180
10 non-working days	862
Total per month	$5,042

The average haul was 12,000 ft. Two trains of ten 12-yd. cars were hauled by two locomotives, the third locomotive being employed in pulling the spreader, getting water for the shovel, switching, etc.

Loading consumed 35 min. for 10 cars loaded by 6 or 7 dipperfuls each, and dumping and latching occupied 5 min., giving a running time to the dump and return of 15 min. Due to delays only 140 cars or 1,540 cu. yd. were loaded per day, giving a monthly output of 30,800 cu. yd. A car held 11 cu. yd. place measure.

The total cost of the work was as follows:

	Per cu. yd.
Excavation	3.6 ct.
Hauling	6.7 ct.
Dumping and raising track	4.7 ct.
Spreading	1.4 ct.
Total	16.4 ct.

Steam Shovel Work on Grade Reduction. Cost data on steam shovel work in grade reduction are given by John C. Sesser in *Engineering and Contracting*, Jan. 2, 1907. The work was done during the season of 1906, by company forces and equipment. The two pieces of work for which costs are given were the Big

Shoal Cut Off and the Little Shoal Cut Off, both located on the Beardstown to Centralia Division of the C., B. & Q. Ry.

The Big Shoal Cut Off was a change of alinement and grades between Sorento and Reno, Ill. On this cut off there were 318,711 cu. yd. of earth to be moved, of which 251,711 cu. yd. were steam shovel work.

On this work two temporary trestles were built, having a total length of 2,961 ft. and an average height of 40 ft. The material for the embankment was hauled from the north, an average distance of 1½ miles. The average depth of cut was 15 ft. The material handled was wet clay. On account of numerous springs encountered, both material and steam-shovel pit were very wet, which delayed this work to some extent. At times the clay would leave the dipper in chunks as large as the dipper itself. This made the dumping of cars from the high trestle rather dangerous and necessitated the locking of the cars to the trestle before they were dumped.

The work being entirely separated from the main line, bunk houses were built for the men employed. Board was furnished the men for $3.75 per week by the boarding contractor.

Water was supplied to the shovel by a 2-in. pipe line, laid on the ground outside of the digging line. At every hundred feet this pipe line had a "T" with a tap, and by means of a long rubber hose water could be supplied the shovel at all times, thus avoiding the usual delay of siphoning water which, in double-shift work, is an item worth consideration. This pipe line was also extended to the cook and bunk houses, thus supplying water for cooking and washing purposes.

The temporary trestle built was designed to carry a loaded train of 5-yd. dump cars before being filled, and the engine in service only after the trestle had been filled. Each bent consisted of two piles, bracing and cap. Second-hand material was used throughout, with the exception of the bracing. Two 8 x 16-in. stringers were used per span, which were built 13 ft. The stringers were recovered, the balance of the material buried in the embankment.

The equipment used on the Big Shoal Cut Off work consisted of the following: One 65-ton Bucyrus steam shovel; 2 switch engines (Class E), weight on drivers, 30 tons; 43 5-yd. dump cars, and 1 Jordan spreader. All of the equipment except the Jordan spreader was second-hand. The second-hand value of this equipment was as follows:

	Value
Shovel	$5,000
Engines	4,400
Dump cars	5,052
Spreader	1,800

The Little Shoal Cut Off work was a change of alinement and grades between Ayers and Durley, Ill., the work necessitating the handling of 188,240 cu. yd. of material. The material handled was about 40% hard pan, it being about as hard a material as the shovel could dig without resorting to blasting. The pit was wet. The material was hauled an average distance of ½ mile and was dumped from a temporary trestle constructed for that purpose. This trestle had a total length of 2,142 ft. and an average height of 35 ft. On this work both shovel and engines were handled over 6% grades and 16° curves very easily.

The equipment used in the Little Shoal Cut Off work was as follows:

One second-hand 65-ton Bucyrus steam shovel, 2 second-hand switch engines (Class E), weight on drivers, 30 tons; 36 second-hand 5-yd. dump cars; 1 new Jordan spreader. The second-hand value of this equipment was as follows:

	Value
Shovel	$5,000
Engines	4,400
Dump cars	4,230
Spreader	1,800

It is interesting to note the cost per yard in place was the same on both jobs. While the equipment and organization were, in a way, about the same at both places, the material handled and the general layout of the work were very different. The organization of the working forces were the same in both cases, the following being the forces engaged on the Big Shoal work:

Day Shift:	Per month
1 general foreman	$118.50
1 steam shovel engineman	125.00
1 steam shovel craneman	90.00
1 steam shovel fireman	55.00
6 steam shovel pitmen, 19 ct. per hr.	
1 conductor	103.50
2 brakemen	69.00
2 enginemen, $4 per day.	
2 firemen, $2.40 per day.	
1 track foreman	75.00
1 assistant foreman, 10 ct. per hr.	
10 laborers dumping cars, 16 ct. per hr.	
38 laborers on track, at 16 ct. per hr.	
1 watchman	45.00
1 timekeeper	45.00
1 pumper	45.00
Night Shift:	
1 steam shovel engineman	$125.00
1 steam shovel craneman	90.00
1 steam shovel fireman	55.00
6 steam shovel pitmen, 20 ct. per hour.	
1 conductor	103.50
2 brakemen	69.00
2 enginemen, $4 per day.	

2 firemen, $2.40 per day.	
1 assistant track foreman	$55.00
8 laborers, $1.75 per day.	
1 watchman, $1.75 per day.	
1 lightman, $1.75 per day.	
1 pumper	45.00

Cost per Day:

	Labor	Supplies	Total
General foreman	$ 2.28	....	$ 2.28
Steam shovel service	22.09	$ 5.50	27.59
Engine service	22.08	9.00	31.08
Car repairing	4.40	....	4.40
Dumping cars	19.00	....	19.00
Track foreman	2.88	....	2.88
Assistant track foreman	2.11	....	2.11
Track work	62.70	....	62.70
Timekeeper	1.73	....	1.73
Pumper	1.73	.65	2.38
Watchman	1.60	....	1.60
Total	$142.60	$15.15	$157.75

Cost per Night:

	Labor	Supplies	Total
Steam shovel service	$ 22.69	$ 5.50	$ 28.19
Engine service	22.08	9.00	31.08
Assistant foreman	2.11	....	2.11
Dumping cars	14.00	....	14.00
Lighting	1.75	2.34	4.09
Pumping	1.73	.70	2.43
Watching	1.75	....	1.75
Total	$ 66.11	$17.54	$ 83.65
Total day and night	$208.71	$32.69	$241.40

The prices at which supplies were bought were as follows: Valve oil, 50 ct. per gal.; black oil, 18 ct. per gal.; signal oil, 34 ct. per gal.; kerosene, 10 ct. per gal.; gasoline, 17 ct. per gal.; shovel and engine coal, $1.48 per ton on Little Shoal Cut Off work, $1.50 on Big Shoal Cut Off; waste, 6 ct. per lb.

For the sake of comparison of the two jobs Mr. Sesser's figures are arranged as follows:

	Big shoal cut off	Little shoal cut off
Date shovel commenced work	Apl. 27	May 21
Date shovel completed work	Nov. 2	Sept. 30
Date shovel commenced night shift	June 20	May 22
Date shovel completed night shift	Oct. 26	Sept. 30
Days steam shovel on work	190	133
Nights steam shovel on work	129	132
Days worked by steam shovel	140	96
Nights worked by steam shovel	88	103
Total days worked by steam shovel (10-hr. shift called a day)	228	199
Shovel laid up due to rain and Sundays (shifts)	57	52
Shovel delayed, moving and shovel failure (shifts)	23	14
Waiting for grading of temporary track (shifts)	11	——
Percentage of 199 days of shovel service delayed	——	16%
Total car output, day shift	47,682	29,774

	Big shoal cut off	Little shoal cut off
Total car output, night shift	27,377	23,116
Cubic yards handled, day shift	160,121	105,818
Cubic yards handled, night shift	91,590	82,422
Cubic yards per car	3.35	3.56
Cubic yards per day (10-hr. shift)	1,104	946
Percentage of night shift output to day shift output	84%	78%

The cost of the work is shown in the following tabulations, all yardage being cross-section measurements.

The progress of the work in the Big Shoal Cut Off from May to Oct., inclusive was 251,711 cu. yd. On the Little Shoal Cut Off 188,240 cu. yd. were moved from May to Sept. inclusive.

COST OF STEAM SHOVEL WORK

Equipment:	Big shoal cut off	Little shoal cut off
Steam shovel, depreciation at 10%	$ 500	$ 500
Engines, depreciation at 5%	200	220
Dump cars, depreciation at 10%	505	423
Spreader, depreciation at 5%	90	90
Total	$ 1,315	$ 1,233
Cost per cu. yd.	0.005	0.006
Bunk Houses:		
Material	$ 757	$ 757
Labor	388	310
Total	$ 1,145	$ 1,067
Cost per cu. yd.	0.004	0.005
Water Supply:		
Material	$ 191	$ 311
Labor	81	300
Total	$ 272	$ 611
Cost per cu. yd.	0.001	0.004
Shovel Work, Labor:		
Shovel service	$ 6,228	$ 5,360
Engine service	6,417	5,303
Car repairs and blacksmithing	771	514
Lighting	185	203
Dumping cars	4,265	3,149
Total	$17,867	$14,529
Cost per cu. yd.	0.071	0.077
Shovel Engine and Car Supplies:		
Valve oil	$ 184	$ 84
Black oil	90	108
Signal oil	17	26
Kerosene	95	366
Gasoline	128	146
Coal for shovel	1,539	1,629

	Big shoal cut off	Little shoal cut off
Coal for engines	1,982	1,200
Waste	48	48
Total	$ 4,483	$ 3,607
Cost per cu. yd.	0.018	0.019
Temporary trestle	$ 9,008*	$ 3,853*
Cost per cu. yd.	0.636	0.031
Track work	$12,438†	$ 7,817†
Cost per cu. yd.	0.050	0.042
Supervision and engineering	$ 610	$ 487
Cost per cu. yd.	0.002	0.003
Grand total	$47,140	$35,205
Total cost per cu. yd.	0.187	0.187

* Cost per lineal foot on Big Shoal work: Labor, $1.30; material, $1.74; total, $3.04. On Little Shoal work cost per lineal foot was: Labor, $1.22; material, $1.51; total, $2.73.

† On Big Shoal work, labor cost was $11,582, and value of track supplies, $7,339; depreciation on latter and actual cost amounted to $8,856, making total cost of track work, $12,238. On the Little Shoal work, the labor cost was $6,673, and value of track supplies, $6,480; depreciation and actual cost on latter amounted to $1,144, making total cost track work, $7,817.

Mr. Sesser states that the limits to which a shovel will work is a most important consideration in planning and estimating work of this kind. It is not economy to work the shovel to its extreme limit in lift and reach. The shovel on this work at times loaded the 5-yd. cars on a loading track 9 ft. higher than the shovel track, with the track centers 22 ft. Loading at such height is very slow work and is liable to wreck the cars badly on account of the lack of clearance for the dipper after emptying. When there is more than one cut to be made and where time is the all important factor, 7 ft. difference in elevation between the shovel and loading tracks allows rapid work and gives better results.

In laying out steam shovel work considerable can be saved at times by taking advantage of the natural conditions of the work as they exist. The track arrangement and the future track arrangements as the work progresses are oftentimes neglected, causing serious delays to the shovel. On few jobs has the writer seen the shovels work to their capacity, on account of poor track arrangement and the consequent inability to keep the cars to the shovel. One must have good running track over the entire work.

Shovel Work at Belle Fourche Dam. The following was published in *Engineering and Contracting*, March 18, 1908, and in *Engineering News*, April 2, 1908. It refers to the cost of work on the embankment of a dam built under contract for the United

States Reclamation Service in South Dakota. This contract was suspended in January, 1908.

The material of which the dam was constructed was a heavy adobe clay with occasional layers of shale. This material was excavated by steam shovels dumping into cars hauled by dinkeys, and also with elevating graders dumping into wagons. (For the cost of work done by the graders see Chap. IX.) The material was dumped, spread and rolled in 6-in. layers, all stones exceeding 6-in. in diameter being removed before rolling. The total volume of the dam is 1,600,000 cu. yd. and during 1906–07 about 32% of this amount was placed.

During 1906 a 75-ton, 2½-cu. yd. dipper, steam shovel was employed, and during 1907 two of these shovels were used. The material was hauled in trains of 10 Western, 4-cu. yd. dump cars by 18-ton Davenport dinkeys. The average haul during 1906 was 1 mile, up a 2% maximum grade, and during 1907, 1 mile down a maximum 4% grade.

Material was spread in 6-in. layers by 4-horse buck scrapers and leveled by a 6-horse road leveler. The tracks were laid so that the earth was spread to a distance of 50 ft. from them, and then were shifted 10 ft. after the completion of every third layer. Sprinkling was done by means of a hose attached to iron pipes in turn connected to a pump. The rolling was performed by a 32-hp., 21-ton, traction engine, and a 12-ton road-roller. The traction engine was very efficient.

Common labor was paid $2.25 to $2.50 and horses $1.15 per day of 10 hr. Coal cost $10.50 per ton delivered. The cost is given below, and the labor account includes the railroad fare of employes, lighting, heating, superintendence, engineer, bookkeeper, timekeeper, blacksmith, machinist, clerk and building rental. These items amount to about 3.3 ct. per cu. yd. The charge for depreciation and repairs is based upon the estimated salvage of machinery and equipment. The supply account includes coal, oil, power, etc. The cost of sinking the artesian wells, each 1,430 ft. deep, and of obtaining suitable water for boiler use has been distributed in the itemized costs.

Cost of Steam Shovel Work on Belle Fourche Dam Embankment, for 1906 and 1907. (Yardage for both years was 305,000 cu. yd. The daily average per shovel was 951 cu. yd. per day of 10 hr.)

Excavation:	Total	Cost per cu. yd.
Labor	$14,215.01	$0.047
Depreciation and repairs	8,892.81	0.029
Supplies	8,189.94	0.027
Total	$31,297.76	$0.103

Hauling:		
Labor	$11,228.17	$0.037
Depreciation and repairs	9,285.76	0.030
Supplies	10,738.00	0.035
Total	$31,251.93	$0.102
Main Track:		
Labor	$ 3,633.29	$0.012
Depreciation and repairs	3,991.96	0.013
Total	$ 7,625.25	$0.025
Rolling:		
Labor	$ 1,891.63	$0.006
Depreciation and repairs	1,361.03	0.004
Supplies	2,176.06	0.007
Total	$ 5,428.72	$0.017
Watering:		
Labor	$ 4,143.20	$0.014
Depreciation and repairs	3,611.69	0.012
Supplies	1,243.43	0.004
Total	$ 8,998.32	$0.030
Grand totals:		
Labor	$ 71,163.44	$0.234
Depreciation and repairs	27,827.08	0.090
Supplies	22,347.43	0.073
Total	$121,337.95	$0.397

Cost of Railway Work. *Engineering and Contracting*, Aug. 5, 1908, describes work that was done in the south on the excavation of a railroad. It comprises a month's work during the fall of the year, when the weather conditions were fairly good, there being only occasional rain storms.

Description of Work. The work consisted of widening one side of a cut, the average height of the excavation being about 40 ft. The water in the side ditch of the cut was turned by boxes under the track into the ditch on the other side, making the work dry. The extra width given to the cut varied from 17 to 21 ft., and this distance would not allow of the regular jack arms being used on the shovel at all times. When this was not possible a special short jack arm was used on one side of the shovel, giving 2 ft. additional clearance. Short jack arms are valuable for such purposes, but the stability of the shovel is greatly reduced by their use.

The railroad company operated its trains through the cut while the work was going on. In all there were about 30 trains a day on one track. Four of these trains were for passenger service and two were carded freights. These six trains had to be cleared by the contractor's dirt trains, ten minutes on their

running time, as furnished by the telegraph operator, kept in the contractor's camp by the railroad company. The rest of the trains were cleared as they approached or else flagged until the dirt trains could take a side track.

The contractor's outfit was a standard gage, and the main line of the railroad was used as a loading track and for hauling the material. The excavated material was hauled two ways to the dumps. One haul averaged a mile and the trains were dumped from the main line, the material being used to widen a long embankment. The average haul to the other dump was 2 miles, and the material was dumped from a temporary trestle, being used to make a new embankment alongside of an old one. Half the material excavated went to each dump, as the time saved in dumping from the trestle compensated for the extra distance hauled.

The material excavated was a red clay mixed with mica and this clay could be classed as "average earth." In the two months 29,800 cu. yd. of this clay were excavated, and 1,200 cu. yd. of solid granite. The granite was in the bottom of the cut, over an area about 200 ft. long. Encountering this rock and having to take it out to grade retarded the progress of the shovel, as during the time the shovel was working in the rock the record of cars loaded each day was not over one-third as large as when working in earth above. The side of the cut was excavated to a ¼ to 1 slope, with the result that several cave-ins occurred. Two of these cave-ins moved the shovel a foot or more to one side and caused delays of 5 to 6 hr. while the shovel was being dug out by hand and the jack arms made solid.

Outfit. The outfit was a new one, the shovel, cars and other tools for the most part having been bought new. The shovel was a Bucyrus 65-ton, with a 2½-cu. yd. dipper, with 14 x 14-in. crowding engines on the boom. The shovel used had only one piece of timber on it, a piece to protect the hoisting chain. The dipper was speeded to make 4 dips per min., and in good material it sometimes did it, loading 12 cars, 36 dipperfuls, in 9 min. The dipper had a lift of 17 ft. and could dig earth 27 ft. to one side, dumping 24 ft. on the other side, thus covering a distance of 51 ft. By placing the shovel on crib work, the shovel could dig 5 ft. below the base of rail. This style of shovel, equipped with extra short arm jacks, is well adapted to grade revision work on railroads, as it is not too heavy to move over wet ground, and has such a range of work as to admit of handling heavy excavation, with a minimum of track laying and shifting. Such a shovel also saves many moves forward in heavy excavation. When the pit is dry, this shovel could be moved forward

6 ft. in from 3 to 4 min., although it has been moved in 2 min. In wet, soft pits, when cribbing is necessary to hold up the shovel and jack arm blocks, from 5 to 10 min. are consumed in moving the shovel forward. The water tank on the shovel had a capacity of about 1,500 gallons.

Two Rogers locomotives were used. These had 16-in. cylinders and four 51-in. driving wheels. They were second-hand engines just from the shop, and each had had a new boiler put on it within 5 years. Their tanks carried about 3,000 gallons of water. Both of these engines did good service.

Each train was made up of 12 Kilbourne and Jacobs, 6-yd., two way dump cars. A record of the cars loaded each day was kept, and this divided into the yardage given in the engineer's estimate showed each car carried 4½ cu. yd. place measurement. Ordinarily 4 dippers of earth loaded a car, so each dipper load amounted to 1⅛ cu. yd. place measurement.

A gasoline pump pumped water direct to the steam shovel, and also pumped water into a 10,000 gal. wooden tank for the locomotives.

A 3⅝-in. Ingersoll drill was used in drilling the rock, steam being furnished from the boiler of the shovel. This drill was capable of putting down a 20-ft. hole.

The cost of the outfit was as follows:

Shovel (65 ton)	$10,000
2 locomotives	10,000
24 (6-yd.) dump cars at $125	3,000
Tanks, pumps, etc., for water	1,000
Rock drill, etc.	400
Blacksmith shop	200
Hydraulic jacks, etc.	400
Small tools	1,000
Camp	1,000
Total	$27,000

Accident. The shovel had been set up and was ready to dig dirt by Saturday night. In moving it into position over ground made soft by the previous month's rains, it careened to one side and fell over, the shovel and boom resting on the main track. 8 by 8 timbers 30 ft. long had been put under the ties to stiffen the track but a rail joint broke over a point where two of these timbers butted together.

The wrecking crane sent by the railroad not being powerful enough to lift the shovel it was decided to place two "deadmen" or anchors in the ground on the side of the shovel away from the main line track and pull the shovel up in this manner. This was done, but owing to the soft ground the first "deadmen" pulled out. New ones were sunk much deeper and ties used to

brace them. A line was hitched around the boiler of the shovel and another to the "A" frame and heavy triple blocks used between the shovel and the deadmen. Then two locomotives were hitched to each of the lines, and started off in opposite directions. The shovel was thus pulled over onto its wheels, setting in the mud.

About midnight rain began to fall and this retarded the work. By 5 o'clock in the morning the track was repaired and traffic was resumed.

On Monday began the work of repairing the shovel. The hydraulic jacks raised the car high enough to build a track under it. Several gear wheels were broken on the boom and new ones were ordered by telegraph and put in place when they arrived. The dipper arm had been bent, and it had to be straightened. All of these things were done by the contractor's own forces in a week, and the shovel was again ready to go to work. The steel house was battered up somewhat, but a handy blacksmith fixed up all but the corrugated plates, and several of these were replaced a few months afterwards.

Cost of Repairs. The cost of the repairs was about $1,100. Of this, $325 was for new parts for the shovel. The railroad company's charges were $80 and the labor charges of men working on the shovel and waiting to go to work, such as train crews, amounted to $700. This included office men and all general expenses. This labor cost has been included in with the two months' work that is being described, as the contractor included it in with his regular pay roll and it was charged against the work done that month. The repair bill and the railroad company's charge have not been included in with the costs to be given below. These were considered charges against the whole job. The total cost of the accident charged against the yardage moved at this point would amount to less than 1 ct. per cu. yd.

Methods of Working. In order to operate the contractor's trains the railroad company furnished a telegraph operator, but the contractor boarded him free of charge. The dirt train operated on "work train orders." The railroad company kept an inspector on the work, and with the company's permission the contractor paid him a salary and put him in charge of the dumps as superintendent of dumps. This was found to be a very satisfactory arrangement.

The temporary trestle was about 25 ft. high. It was built of round poles, costing 3 ct. per ft. delivered on the ground. The braces used were 3 x 8 in., and the stringers were 12 x 12, 18 ft. long, the bays of the trestle being 16 ft. long. This timber (pine) cost $10 per M ft. B. M. The trestle was erected by a sub-con-

tractor for $3 per M. This gave a cost for the temporary trestle complete of 1¾ ct. for each cu. yd. dumped from the trestle. Only one-half the material excavated in these two months went to this trestle.

Cost of Work. Below is given the total cost of the two months' work, including all cost to the contractor except the expenses incurred at his home office. With a large number of jobs going on this item of expense would be small. A 10-hr. day was worked. The following prices were paid for supplies:

Black powder, per keg	$1.25
Dynamite, per lb.	0.11
Exploders (average)	0.06
Fuse, per 100 ft.	0.45
Caps, per 100	0.60
Coal (run of mines), per ton	3.25

The total cost of the work for the two months was:

Office and Superintendence:	
Engineer in charge	$ 300.00
1 bookkeeper	130.00
1 clerk	80.00
1 telegraph operator's board	30.00
1 night watchman	70.00
1 cook and 1 flunky	130.00
1 superintendent	280.00
Oil for camp	14.00
	$1,034.00
Loading:	
1 shovel runner	$ 280.00
1 craneman	180.00
1 fireman	60.00
2 pitmen	132.50
4 pitmen	212.00
Blasting:	
Steam drill and drilling	$ 42.50
Powder and dynamite	52.00
Exploders, etc.	16.00
73 tons coal	237.25
Oil, gear shield, etc.	21.00
Repairs to shovel	15.00
	$1,248.25
Hauling:	
2 locomotive enginemen	$ 360.00
2 firemen	160.00
2 conductors	300.00
4 flagmen	212.00
1 car oiler	53.00
200 tons coal	650.00
Engine and car repairs	30.00
Oil, waste, etc.	50.00
	$1,823.00

Dumping:	
1 inspector	$ 80.00
1 fireman	132.50
12 men	636.00
1 fireman	159.00
20 men	1,060.00
Temporary trestle, 16,100 cu. yd. at 1¾ ct.	281.75
	$2,349.25
Miscellaneous:	
1 blacksmith	$ 169.00
1 blacksmith helper	53.00
Extra gang:	
1 foreman, 1 month only	54.00
10 men, 1 month only	270.00
	$ 546.00
Total labor and supplies	$7,000.00
Interest and depreciation	1,080.00
Grand total	$8,080.50

Interest and depreciation does not include repairs and is charged at the rate of 2% per month, worked. This is an ample allowance.

The output of the shovel per day worked was nearly 700 cu. yd., but for the full number of working days in the two months the output per day averaged about 600 cu. yd. The average cost per cu. yd., including both earth and rock, for the details of the work, was:

Office and superintendence	$0.033
Loading	0.040
Hauling	0.059
Dumping	0.079
Miscellaneous	0.018
Interest and depreciation	0.035
Total per cu. yd.	$0.264

Where earth and rock are moved jointly it is not possible to keep the actual cost of each class of excavation, but the total cost of the two can be kept, and a comparative cost with the contract price for the earth and rock can be calculated. This is a cost that can be relied upon.

To illustrate the comparative cost an example will be given. If earth is being excavated for 35 ct. and rock for 75 ct. and 10,000 cu. yd. of earth and 5,000 cu. yd. of rock are excavated, and there is made a profit of 15% on the work, then the cost of the earth excavation will be 85% of 35 ct. or 29¾ ct., and the cost of the rock excavation will be 85% of 75 ct., or 63¾ ct.

Such costs on this work figured out, there being a profit made of nearly 20%, gives for earth the following:

Office and superintendence	$0.032
Loading	0.037
Hauling	0.054
Dumping	0.072
Miscellaneous	0.017
Interest and depreciation	0.033
Total per cu. yd.	$0.245

The cost of the rock excavation per cu. yd. was:

Office and superintendence	$0.085
Loading	0.098
Hauling	0.148
Dumping	0.190
Miscellaneous	0.046
Interest and depreciation	0.089
Total per cu. yd.	$0.656

Cost of Excavating Gravel in a Canal. Mr. J. B. Brophy furnishes the following data to *Engineering and Contracting*, Oct. 14, 1908. The work was done at the canal near Trenton, Ontario. The material was a gravel. The cutting was 10½ ft. deep and was side cutting, the material being loaded into cars as high as the machine would reach. From June 1 to 13 the shovel excavated 16,000 cu. yd., the average haul being 1,200 ft. From June 15 to 30, 20,000 cu. yd. were excavated, the average haul being 1,400 ft. This makes a total of 36,000 cu. yd. with an average haul of a little more than 1,300 ft.

The outfit used on the work consisted of the following: A 65-ton steam shovel with a 2½-cu. yd. dipper, made by the Bucyrus Steam Shovel Co., of South Milwaukee, Wis. Two 12-ton Porter dinkeys. About ⅛-mile of track was used and 22 dump cars of 4 cu. yd. capacity. The cost of this outfit was approximately as follows:

65-ton shovel	$ 9,000
2 (12-ton) dinkeys	5,000
22 (4-yd.) dump cars at $230	5,060
16 tons 20-lb. rails at $32	512
1,000 ties at 10 ct.	100
Total	$19,672

Estimating 2% for monthly interest, depreciation and repairs, gives a charge per month of about $390.

The shovel worked 12 hr. per day, but the track gang and water wagon only worked 10 hr. per day. We assume the standard wages on this class of work, which are:

Shovel runner	$125 per month
Craneman	90 per month
Fireman	60 per month
Watchman	40 per month

Dinkey runners	$3.00 per day
Brakemen	2.00 per day
Foremen	3.00 per day
Oiler	1.75 per day
Laborers	1.50 per day
Water boy	1.00 per day
Team (with driver)	5.00 per day

During the month 26 days were worked. The total cost of the work and the organization of the forces were:

Loading:	
1 shovel runner	$125.00
1 craneman	90.00
1 fireman	60.00
4 pitmen	156.00
1 team hauling water	180.00
50 tons coal at $5	250.00
Oil, waste, etc.	10.00
Total loading	$871.00
Hauling:	
2 Dinkey runners	$156.00
2 brakemen	104.00
1 oiler	45.50
1 trackman	39.00
60 tons coal at $5	300.00
Oil, waste, etc.	16.00
Total hauling	$660.50
Dumping:	
1 foreman	$ 78.00
16 laborers	624.00
1 water boy	26.00
Total dumping	$728.00
Track gang	
1 foreman	$ 78.00
5 laborers	195.00
1 superintendent	150.00
1 timekeeper	65.00
1 watchman	40.00
Interest, depreciation and repairs (estimated)	390.00
Grand total	$3,177.50

The cost per cu. yd. of material excavated was:

Superintendence	$0.007
Loading	0.024
Hauling	0.018
Dumping	0.020
Track work	0.008
Interest, depreciation and repairs (estimated)	0.010
Total per cu. yd.	$0.087

The yardage moved in one shift is very large for this size shovel.

A High Steam Shovel Output. *Engineering and Contracting*, Aug. 25, 1909, gives the following: During the month of March, 1909, a 60-ton shovel moved 37,000 cu. yd. of material from a very wet cut, on the Carolina, Clinchfield & Ohio Ry. The quantity of water encountered is indicated by the fact that the dinkey track required corduroying with two layers of poles for its entire length of 12 ft. on each lift. This same shovel also moved 35,000 cu. yd. in January and 25,000 cu. yd. in February, making a total of 97,000 cu. yd. for three winter months. This fine record is due in part to the excellent organization of the contractors and their skill in taking advantage of every opportunity of increasing the output.

As a comparative cost per cu. yd. to the contractors for this shovel during the month of March, actual figures as obtained from them are given below:

March Estimate, 37,000 cu. yd.; Working Days, 24

Labor	$2,076.27
Coal	480.00
Supplies	25.00
Repairs	95.00
Oil waste	50.00
Depreciation	170.00
Total	$2,896.27
Cost per cu. yd.	$0.08
Plus trestle	.01
Total	$0.09

The distributed cost is as follows:

	Per cu. yd.
Loading	$0.028
Hauling	0.018
Dumping	0.019
Trestle	0.010
Maintenance	0.015
Total	$0.090

This material was handled by three 12-ton dinkeys, each hauling nine 4-cu. yd. cars and side dumped from a 65-ft. fill.

Engineering News, Apr. 21, 1910, states that all records hitherto made on the Panama Canal were broken by Steam Shovel 213 working in the Culebra cut on March 22. According to the *Canal Record* of March 30, this shovel excavated in eight hours' working time 4,823 cu. yd. of rock and earth, measured in place, and loaded 235 Lidgerwood cars. The shovel was actually working five hours and twenty minutes of the time, so the actual average rate of work was 15 cu. yd. per min. The distribution of time for the eight hours was as follows:

	Minutes
Time loading	320
Moving up 20 times, 5 minutes each	100
Waiting for cars	55
Coaling shovel	5

The cost for labor for running the shovel on this day was $30.21, and the cost for supplies was $24.59, making a total expense of $54.80, itemized as follows:

Labor	
1 engineer, one day, at $7.56	$ 7.56
1 craneman, one day, at $6.48	6.48
1 foreman, one day, at $2.83	2.83
2 firemen, one day each, at $1.67	3.34
1 laborer, 8 hours, at 13 ct.	1.04
7 laborers, 8 hours each, at 16 ct.	8.96
Total labor	$30.21

Supplies	
5¼ tons of coal, at $4.41	$23.15
3 gallons of car oil, at 18 ct.	.54
2 gallons of valve oil, at 31 ct.	.62
2 lb. of cup grease, at 10 ct.	.20
1 lb. gear grease, at 8 ct.	.08
Total supplies	$24.59
Grand total	$59.80

This is 1.14 ct. per cu. yd.

Steam Shovel Work on the Western Maryland Ry. *Engineering and Contracting*, Apr. 26, 1911, gives the cost of excavating during a record month by a 70-ton Bucyrus shovel, one of 13 shovels used on the Cumberland-Connellsville extension

The plan of taking out the cut required a switch-back in order to get the material to the fill. The distance from the center of gravity of the cut to the center of gravity of the fill was 1,600 ft. by dinkey track measurement, and a 3.5% grade was used from the mouth of the cut, to a point of switch-back, a distance of 950 ft. A passing siding open at both ends, of sufficient length to hold a dinkey and 12 dump cars, was placed about mid-way of the switchback and as soon as the loaded train cleared the uphill switch the empty train had a clear right of way to the shovel.

The record output of 37,100 cu. yd. in 30 working days (one 10-hr. shift) was made during the month of March, 1911.

The grade left by the shovel in making each cut was always in a uniform condition for moving the shovel back for a new cut and when the dinkey track was thrown, it required very little surfacing to put it in order. A gang of 1 foreman and 4 men maintained the track and kept it in such good condition that

it was possible for a 16-ton dinkey to haul twelve 4-cu. yd. cars at a high speed.

A dump gang of 1 foreman and 8 men was able to take care of the material as it came to the fill and at the same time keep the dump in good shape. In beginning the fill (that is when the material was dumped from the trestle), planks were extended from each side in order to hold a foot walk for the men, so the entire train could be dumped from the trestle. In doing this there was always enough material deposited on the bottom sills of the trestle bents to prevent the main fill from pushing the trestle down.

The method of raising the fill from the trestle (which is below grade) to a height to allow for shrinkage, is novel. As the trestle on side hill work is always placed on the up-hill side of the center line, by elevating the down-hill rail, it prevents

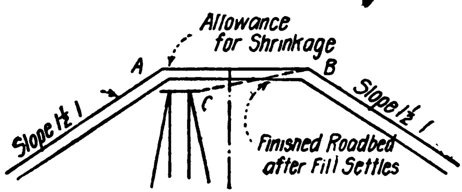


Fig. 50. Section of Fill.

the cars from being overturned in dumping (requiring very little chaining, only when the cars are loaded with heavy boulders) and at the same time the dump is being raised to the proper height, *C* to *B*, at the required width of roadbed on the lower side, as shown by Fig. 50; the fill is then made from *B* to *A*.

For the first 15 days the shovel was working in a hard sandstone ledge about 12 ft. thick, and, in shooting, the material broke in large boulders which required considerable chaining. A total of 16,000 cu. yd. were moved during this time. During the latter 15 days the shovel was working in black shale and moved 21,100 cu. yd.

There were five moves during the month, a distance of 500 ft. each time. There was an average loss of 1 hr. each day during the month in shifting track on the dump. The total number of cars for the 30 days were 12,443. The largest day's run was 836 cars, the average number of cars per day was 415, and the average yardage per car was 2.98 cu. yd.

The cost of the work, 37,100 cu. yd. for the month, was as follows:

Total expense of the shovel, including superintendent, walking boss, shovel and dinkey crews and all other labor	**$3,623.00**	**$0.09¾**
Explosives	**302.00**	**0.00⅘**
Trestle	**229.00**	**0.00½**
Coal	**235.00**	**0.00¾**
Oil and waste	**32.00**	**0.001½**
Water	**112.00**	**0.00⅓**
Interest on plant	**110.00**	**0.00⅓**
Depreciation	**460.00**	**0.01¼**
Total	**$5,103.00**	**$0.13¾**

The equipment comprised one 70-ton Bucyrus shovel, two 16-ton Vulcan dinkey engines, 24 4-cu. yd. Western dump cars, 54 tons 60-lb. rail and one Cyclone well drill.

Excavation on the Chicago, Milwaukee and St. Paul Ry. ***Engineering and Contracting,*** **July 28, 1909, gives the following: On the construction work of the C. M. & St. P. coast extension there were many large fills. From one steam shovel pit, the Newcomb, some 250,000 cu. yd. of material was taken.**

The following tabulated statement shows the data of and cost of operations at this pit for the month of Mar., 1909: —

Shovel — Bucyrus No. 453, 2½-yd. dipper, 65-ton.
Engines — Prairie type, 3 in use, tractive power, 33,300 lb.
Cars — Western dump, average load 12.6 yd.
Trains — 1 engine handling 13 loads, and caboose per train.
Yardage, 68,000 cu. yd., handled in 27 working days, 10 hours each.
Yard miles, 308,780.
Average haul, 4.54 miles. Rate of ascending grade against loads, 88 ft. per mile.

Labor Loading:	
Steam shovel pay roll	**$1,815.64**
Section labor	**99.94**
Total labor	**$1,915.58**
Work train service:	
Conductors, 95.8 days at $3.68	**$ 352.54**
Brakemen, 191.6 days at $2.53	**484.75**
Engineers, 95.8 days at $4.40	**421.52**
Firemen, 95.8 days at $2.95	**282.61**
768 tons of coal at $4	**3,072.00**
1,916,000 gal. water (255,466 cu. ft. at .07 per 100 cu. ft.)	**178.83**
95.8 engine days for supplies at $0.32	**30.66**
81.0 engine days for depreciation at $2.03	**164.43**
81.0 engine days for repairs at $3	**243.00**
81.0 engine days for interest at $2.03	**164.43**
Total	**$5,394.77**
Coal Used by Steam Shovel:	
172.8 tons coal at $4	**$ 691.20**
Total	**$8,001.55**

Less Comp. Credits (Profits)	
Boarding comp.	$ 174.27
Commissary	15.74
Total credits	$ 190.01
Total cost, net	$7,811.54

The cost was, therefore, 11.5 ct. per cu. yd. for 68,000 cu. yd. handled during the month.

Excavation on the North Shore Channel, Chicago. Sections Nos. 4 and 5 of the North Shore Channel of the sanitary district of Chicago were contracted to James O. Hayworth. The work of drag line machines on these sections was described in *Engineering and Contracting*, April 27, 1910.

The top 10 ft. consisted of a clay which could readily be dumped from dump cars, but below this the clay was heavy and tenacious and came in large lumps. It was excavated by a *70-ton Vulcan* steam shovel with a 3-cu. yd. dipper. The steam shovel loaded into Western 3-cu. yd. dump cars which were handled by Davenport locomotives out of the cut and onto the crib piers behind which the spoil was dumped.

These cars were dumped in the usual way until the sticky clay noted above was met, then they would not dump properly. A derrick was then arranged to do the dumping. A sling was devised which would hook into and lift the car body from the trucks and by winding up on the engine would tilt the body and empty it.

The cost of excavation, as kept by the engineers, was as follows for 1908, when 194,280 cu. yd. were excavated: An 8-hr. day was worked and wages paid were as follows:

Men in dump per day	$1.50
Men around shovel per day	1.75
Steam shovel enginemen per month	$125 to $150
Steam shovel cranemen per month	90

The value of the excavating plant used was $16,035, and the assumed depreciation chargeable to Section 1 was $16,035 × 50% = $8,017.

The total amount expended on excavation (194,280 cu. yd.) in 1908 was as follows:

	Total
Materials:	
Operation	$ 8,639
Repairs and plant	7,156
Totals	$15,795
Per cu. yd.	$0.081
Labor:	
Operation	$32,241
Repairs and plant	3,295
Totals	$35,536

Per cu. yd.	$0.182
Grand totals	$51,331
Per cu. yd.	$0.264

The items making up these totals were as follows:

Materials:	Operation	Rep. & Plnt.	Total
Shovel	$1,208	$1,502	$ 2,710
Dinkeys	753	1,148	1,901
Track	0	2,222	2,222
Dump	259	0	259
Cars	216	1,863	2,079
Coal	6,066	0	6,066
Office	0	360	360
Insurance	0	0	0
General	136	61	197
Totals	$8,638	$7,156	$15,795
Labor:			
Shovel	$ 8,728	$ 820	$ 9,548
Dinkeys	5,876	359	6,265
Track	5,951	0	5,951
Dump	9,146	0	9,146
Cars	34	1,975	2,009
Coal	585	0	585
Office	0	8	8
Insurance	606	0	606
General	1,315	103	1,418
Totals	$32,241	$3,295	$35,536

The costs of operation in excavation were distributed as follows per cu. yd.:

Steam Shovel:	
Labor	$0.0450
Coal	0.0172
Supplies	0.0062
General	0.0034
Total	$0.0718
Transportation:	
Labor	$0.0310
Coal	0.0171
Supplies	0.0051
General	0.0009
Total	$0.0541
Track:	
Labor	$0.0314
General and supplies	0.0009
Total	$0.0223
Dump:	
Labor	$0.0478
Supplies	0.0012
General	0.0023
Total	$0.0513
Grand total	$0.2095

Steam Shovel:	
Labor	$0.0021
Materials	0.0035
General	0.0004
Total	$0.0063
Transportation:	
Labor	$0.0061
Material	0.0077
General	0.0004
Total	$0.0142
Track:	
Materials	$0.0057
General	0.0004
Total	$0.0061
Grand total	$0.0266

In figuring the net costs of repairs and plant charges the total estimated amount of excavation on the section, or 390,000 cu. yd. has been used as the divisor. The reason for this is that the repair and plant charges itemized were all that were necessary to put the plant in shape to complete the work. Summarizing we have:

Operation	$0.209
Repair and plant charges	0.027
Depreciation on plant	0.021
Total per cu. yd.	$0.257

Yearly Average Outputs on the Hill View Reservoir. The yearly output of steam shovels in building the earth embankment for the Hill View Reservoir, New York City, is given by Arthur Tidd, in *Engineering News*, Sept. 9, 1915. The formation was of very hard packed, dense, glacial drift, containing many stones and boulders but no ledge rock. The material was well graded from a coarse sand down to a very fine rock flour, and was a most excellent one for a reservoir embankment.

All the material was excavated by steam shovels, and about 70% sent out on trains. As long as the complete steam shovel plant could be operated (that is until the bank became so narrow on top that the dumping area was restricted) the material was taken out of the basin by two tracks, one at the north and one at the south end, using pushing engines when the grade required them. Both lines were relocated and regraded several times as the banks rose. The steam shovels used for the bulk of the excavation were four heavy 70-ton shovels, and four light 30-ton shovels. The large shovels worked in the heavy cuts, taking the full depth (40 ft. at the deepest point) at one time.

These cuts were, however, shot ahead of the shovel with black powder. The small shovels took the lighter cuts, and in a few cases ran through in two lifts. The material was handled in 4-yd. side-dumping cars in 10-car trains by 10- to 15-ton locomotives running on 3-ft. gage track laid with 65- to 70-lb. rails.

A large number of boulders of all sizes up to 1 yd., and in some cases 2 or 3 yd. in volume, were encountered everywhere throughout the cuts, and their handling became an important factor in the general excavation problem. Many boulders were saved for future use in paving, riprap or for crushed stone, but the accumulation interfered so much with succeeding excavation operations that the following seasons as many as possible were sent out onto the bank. A large force using a portable gasoline air-compressor for drilling was employed continuously breaking up boulders. Winter work helped somewhat, but the problem was an ever present and troublesome one.

Although monthly outputs ranging from 20,000 to 24,000 cu. yd. per 70-ton shovel were not uncommon in the early part of the work, the best year output was 190,000 cu. yd., and the average yearly output for each of two shovels for five years was 120,000 cu. yd. The shovels were in use practically all the time. The length of working day was 8 hr., and one shift daily was worked. The average yearly output for each of three 30-ton shovels was 49,000 cu. yd., or about 40% as much as with the 70-ton shovels.

A Good Steam Shovel Record. The *Excavating Engineer*, Oct., 1915, states that a 3-yd., 70-ton Bucyrus Steam Shovel, working in hard-packed sand with loam and gravel, at Providence, R. I., averaged 2,816 cu. yd. per 10-hr. day for 12.5 days, loading into 4-yd. cars. The face averaged about 12 ft. high. The material was hauled in three trains, of fourteen 4-yd. cars each, by 20-ton, 36-in. gage, locomotives, an average distance of about 1/8 mile. During the 12.5 days about 0.5 day was lost the first day, and two other days were devoted to moving back to a new cut.

Records on a Large Cut for Track Depression. *Engineering and Contracting*, June 28, 1916, gives the following:

A 900,000-cu. yd. cut, which eliminates 39 crossings at grade was made in Minneapolis, Minn. In this work the tracks were lowered to give a clearance under bridges of 18½ ft.; this necessitated a cut averaging 22 ft. in depth. The work was done by the operating department of the Chicago, Milwaukee & St. Paul R. R. with company forces.

The total depth of the cut was made in from 5 to 7 cuts,

depending upon the depth carried. These cuts were generally carried for a stretch of about eight blocks at a time. The usual method of procedure was to use one track as a loading track while the shovel was making as deep a cut as possible to one side. This usually averaged about 8 ft. When this cut was completed to the required distance, a new track was laid here and used as a loading track while the shovel was shifted to the other side.

The shovel used was a 65-ton Bucyrus equipped with a 2½-yd. dipper. This shovel was shipped from the manufacturer's shops in the spring of 1907 and has been in steady service for the past eight years. Three dirt trains were used, consisting of 25 (12-yd.) Western air dump cars. Each train was hauled by a class C-2 (2-8-0) locomotive.

Below is a statement, prepared by J. G. Wetherell, assistant engineer, who was in direct charge of the work, for the operating department, for shovel operation from April 19 to July 23.

Total amount of excavation for season, cu. yd.	195,908
Total number of days shovel worked	82
Number of cuts shovel made	8
Total distance shovel excavated (total length of cuts), ft.	16,076
Average distance excavated per day shovel worked, ft.	196
Average number of hours shovel worked per day, hr.	8.80
Total number of cars loaded	17,107
Average number of cars loaded per day	208.6
Average number of cu. yd. per car, cu. yd.	11.46
Average number of cu. yd. excavated per day	2,389.1
Average distance excavated material hauled, miles	5.28
Greatest excavation for 1 month (June), cu. yd.	72,934
Average daily excavation for June, cu. yd.	2,805

Delays amounted to 12% of the total time, distributed as follows: 3.4%, moving shovel from one cut to next; 5.3%, no cars, due to trouble at the dump or to main line being used for other purposes; 1.3%, rain; 0.2%, shovel breakdowns; 0.8%, derailments in cut; 1.0%, miscellaneous.

Stripping in the Anthracite Coal Region. The following is from a paper by J. B. Warringer in the Am. Inst. M. E., as abstracted in *Engineering and Contracting*, Jan. 17, 1917. The work is stripping earth overlying coal in Pennsylvania.

The equipment required for a one-shovel operation is about as follows:

1 70-ton shovel.	1 steam drill.
3 18-ton locomotives.	1 water tank.
20 5-yd. dump cars.	1 boiler.
1 star drill.	1 blacksmith shop.

Necessary rails, sills, pipe lines, tools, etc.

The total capital outlay for such an outfit is approximately $30,000.

The average force required to operate a one-shovel stripping consists of about 35 men, roughly as follows:

1 foreman.
1 shovel engineman.
1 craneman.
1 fireman.
1 watchman.
2 laborers.
4 jackmen.
3 locomotive enginemen.
1 dump boss.
6 dumpmen.
1 track boss.
2 trackmen.
2 drillers, 8 helpers.
1 boiler fireman.
1 blacksmith and helper.
2 coal diggers.
1 driver.
1 switchboy.

The wages paid these men amount to $2,100 per month. The shovel engineman is paid $140 a month, the craneman $95; locomotive engineman $0.25 per hr. These rates are all subject, however, to the recent increases granted the mine workers, ranging from 7 to 15%.

The method of opening a stripping with either a Bucyrus 70-ton shovel or a Marion 60-ton shovel, which are the two

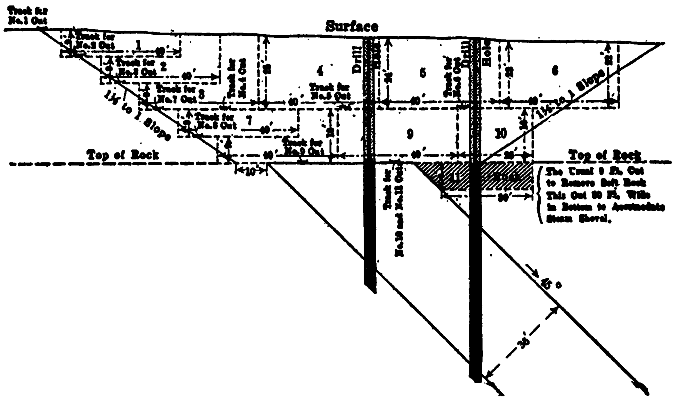


Fig. 51. Method of Opening a Stripping.

types most widely used in anthracite stripping work, is as follows (Fig. 51): For the first cut the track is laid on the surface along one limit of the stripping, usually the bottom rock side, and the shovel cuts down grade alongside the track until a depth of 9 ft. is reached, this being the maximum cut that the shovel can take and load overhead. When the first cut is completed for the length of the stripping, the track is laid in this cut and the shovel again cuts down grade until a depth of 9 ft. below the first cut is reached. The shovel then continues cutting toward the other limit, the additional depth being determined by the depth of surface over the vein up to 30 ft., which is considered the proper maximum height for a clay cut.

In working by the above method, it is necessary to leave a bench at least 13 ft. in width for the laying of the track. Local conditions, as a rule, render it impossible to maintain any such plan for the entire life of a stripping.

The first cut as described above is always the first made in a stripping except in the case of what is known as a side-hill stripping. Here the track is laid on the surface and the shovel started at an elevation that will give the required cut at the vertical limit.

Rock cuts are usually made from 22 to 25 ft. in height.

The tracks to the dump are always on an ascending grade of 1%, but usually higher. Four per cent is common, and grades as high as 7% have been used. The grade of the tracks in the stripping pit is governed by the necessary rise in elevation to reach the dump. The locomotives used vary in size up to 20 tons, the latter being about the heaviest type that can be used safely on a dump of any height. A 20-ton locomotive will push:

10 4½ cu. yd. cars on a 1% grade.
8 4½ cu. yd. cars on a 3% grade.
6 4½ cu. yd. cars on a 4% grade.

The general and best practice for stripping tracks is to use 60-lb. rails and nothing under a No. 6 frog. Curves should be kept to under 10°, but 20 to 25° curves are used, especially in forming a dump.

Dumps are made of all heights and sizes. There is less maintenance cost with heights of about 25 ft., as higher dumps tend to settle and slip in wet weather.

The cars most widely used are side-dump cars having capacities of 4, 4½ and 5¼ cu. yd. Some 8 and 10-cu. yd. cars have been used with success.

Under proper conditions outputs as high as 30,000 cu. yd. per month have been obtained for one shovel in clay. The average is about 18,000 cu. yd. per month in clay, varying considerably according to season as shown in Fig. 52.

Hoisting Planes. If the stripping is not too deep, all the excavated material can be removed by locomotives. In many cases, however, this is not feasible, and hoisting planes must be resorted to. Practically without exception, even in the largest operations, these are single-track planes operated by small second-motion hoisting engines with a capacity of about 150 dump cars per day, or about the output from one shovel. The practical problem involved in putting these planes down along the steep sides of the average pit is often a serious one. Some of the planes are anchored on a slope of 50 to 60° pitch by bars sunk into the solid rock to which the roadbed is tied, presenting a

very interesting sight. While nothing can be said against these small hoists for a one-shovel stripping, it is undoubtedly bad practice to use them in the larger operations employing two or more shovels. There are practically none of these that cannot be laid out so that the output from two shovels can be brought to the foot of one plane, and this plane should be equipped with a hoist capable of handling with ease 300 and more cars per day. This plane can be either single track or double track, but the grade should be maintained at about 20°, which is the average for the single track planes now in use.

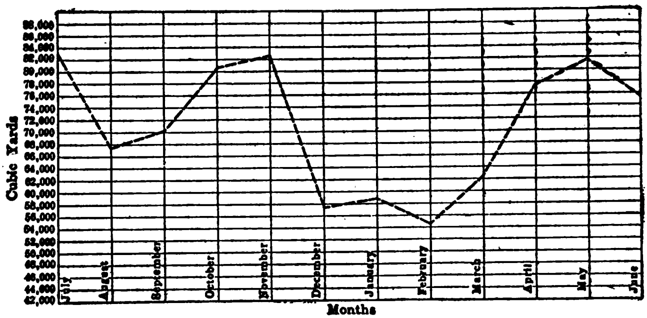


Fig. 52. Stripping Operations of One Company Averaged by Months Over a Period of 4 Years.

Some figures have been worked up showing a comparison of cost of the two varieties of planes, taking a double track plane handling only the output of two shovels which would allow the greatest advantage of comparison possible to the small hoist. The first cost of the small hoist job is very low, as the hoist itself is usually picked up second hand around the collieries. It would be something as follows for a 300-ft. length of plane:

Hoist	$ 500
Tracks, track material, rope, etc.	700
Grading for hoist and plane	1,000
Total	$2,200

For the double track plane with the larger hoist the figures would be:

Tracks, track material, rope, etc.	$1,100
Hoist	5,000
Hoist house, pipe line, etc.	800
Grading for hoist and plane	3 000
Total	$9,900

To operate the single-track plane two top-men, two bottom-men, one locomotive engineman, one hoist engineman, four men and a boss on the dump, are required, while the double-track plane would require three top-men, three bottom-men, two locomotive enginemen, one hoisting engineman and seven men and one boss on the bank.

The comparative cost would be as follows:

	Single track	Double track
Labor per day	$17.88	$26.21
Power	4.30	6.48
Interest and depreciation, 15%	1.00	4.00
	$23.18	$36.69

Figuring 150 cars for the single-track plane, the operating cost per car would be $0.155 and at 300 cars for the double-track plane $0.122 or a difference of $0.033 per car.

The location of the limits for a stripping are set on a line where the normal slope of the overburden figured from the bottom of the final cut intersects the surface. Naturally a shovel cannot cut to any such slope and must accomplish the same result by a series of steps. The normal slope that earth of a clayey nature will take is about 1 to 1. Sandy ground requires 1½ to 1 or even 2 to 1, while rock can be cut nearly vertically if the height of bank does not exceed one shovel cut. For greater depths, ½ to 1 must be allowed or even 1 to 1 if the rock is of a shaley nature. The importance of having the foot of the stripping slope well back from the bottom rock of the coal, to prevent the washing of overburden into the exposed vein by rains, is very great. The standard width for this ledge or berm is 10 to 15 ft.

Prices of Non-Revolving Traction Shovels. For low bank work in average earth, where the amount to be excavated is small, 20 to 35-ton shovels, usually fitted with traction wheels, but which can be arranged with railroad trucks, cost as follows, prior to the war:

Shipping Weight	Dipper Capacity	Clear height of lift: Traction wheels	Clear height of lift: R. R. trucks	Price
22 tons	¾ cu. yd.	12′ 2″	13′ 2″	$4,750
32 tons	1¼ cu. yd.	12′ 8″	13′ 8″	5,600

Shovels of small size usually have vertical boilers.

A 35-ton shovel, with a very high crane which increases the width of cut about 7 ft. and the height of lift about 6 ft., costs $5,800. These are regularly equipped with a 1¼-yd. dipper.

Shoveling Soft Shale. On the P. C. & W. R. R. in Ohio, a 35-ton Vulcan traction shovel was employed in loading blasted

shale into dump cars, at the time the author was on the work in 1903.

The material was drilled with hand churn drills, holes being 15-ft. deep. Each hole was chambered with 1½ sticks of dynamite and exploded with 75 lb. of black powder. About 4 holes per day were fired.

The shovel had a 1½-yd. dipper. Six 3-yd. dump cars were loaded in 11 min. Only one train was used, the shovel waiting

Fig. 53. Non-Revolving Traction Shovel with 2½-cu. yd. Dipper.

6 min. while the train was hauled 800 ft. to the dump and returned by a dinkey. The dumping of the train, one car at a time, through the trestle occupied 3 min. The locomotive therefore travelled 1,600 ft. (going empty on an 8 or 10% grade) in 3 min., or at the rate of about 6 miles per hr. Part of the waiting time is occupied by the shovel in moving, each 4 ft. move requiring about 3 min.

The force employed was as follows:

1 foreman	1 brakeman
1 shovel runner	1 pumpman
1 craneman	6 drillers
1 fireman	1 blacksmith
3 pitmen	2 dumpmen
1 locomotive runner	

The shovel consumed 28 bushels of coal and the locomotive 7 bushels per day. (Note — A bushel of coal weighs approximately 75 lb.)

About 500 cu. yd. were excavated in a 10-hr. day.

On another section of this work a 65-ton shovel was operating at a disadvantage because only one train of 6 cars was provided. The train was loaded in 5 min., but 10 min. were lost while waiting for the return of the empty cars.

A Steam Shovel Loading Wagons. The following is given by John S. Ely in *Engineering News*, July 14, 1904:

A 45-ton Bucyrus steam shovel equipped with a 1¾-yd. dipper, working in soft material, excavated a cut 8 ft. deep, and 22 ft. wide. Dump wagons were loaded with one dipperful each. The

Fig. 54. Marion Model 250 Stripping Shovel.

speed of the teams ranged from 160 to 180 ft. per min. The average speed being 167 ft. the haul one way varied from 1,250 to 1,500 ft. and was partly up hill and partly down. The wagons were dumped without stopping.

On one occasion when the haul was only 200 ft., 6 wagons kept the shovel busy. From 2:40 to 2:44½ P. M., 4 wagons were loaded, then the shovel moved ahead 5 ft. in ½ min. and waited 2 min. for a wagon. From 2:48 to 3:02 P. M., 27 wagons were loaded and then the shovel moved ahead 5 ft. in 2 min. From 3:05 to 3:10 P. M., 12 wagons were loaded. Between 2:40 and 3:10 the first wagons made 2 round trips. In the above run about half the time was lost waiting for wagons, there being 26 wagons. The dipper loaded at the rate of 3 wagons per min.,

but allowing 10 min. out of every hour for moving forward, an average of 2½ wagons per min. should have been maintained. This gives us this rule for obtaining the number of wagons required for steam shovel work: To obtain the number of wagons multiply the haul in 100-ft. stations by 3.

The cost of work was as follows: 1 steam shovel runner at \$150 per month, or 60 ct. per hr.; 1 cranesman at \$125 per month, or 50 ct. per hr.; 1 fireman at \$50 per month, or 20 ct. per hr.; 10 pitmen at 15 ct. each, or \$1.50 per hr.; 1½ tons of coal per day at \$2.20 per ton, or 33 ct. per hr.; incidentals at about 10 ct. per hr.; total, \$13.23 per hr. of shovel time. Hauling cost \$6.00 per day.

On the day the record was kept the shovel out-put was 1,043 wagon loads, the best day's record was 1,078 wagons containing about 1⅙ cu. yd. each.

Mr. Ely believes the output should be 150 wagons or 180 cu. yd. (place measure) per hr.

Large Revolving Shovels. The largest steam shovels built are of the revolving type. Machines weighing 360 tons are in use, and are sufficiently successful to make it seem probable that the limit in size is not yet reached. These machines are chiefly employed for stripping the over burden from ore and coal.

Fig. 55 and the following table of specifications give an idea of the possibilities of this machine.

TABLE OF SPECIFICATIONS OF MARION COAL STRIPPING STEAM SHOVELS

1⅛ to 1 Slope of Spoil Bank

MODEL 271

5-Yd. Dipper, 90-ft. Boom

A	C	C'	D	E	F
40'	57'	57'	22½'	4'	18½'
42'	51½'	51½'	21½'	4'	17½'
44'	40'	40'	21½'	4'	17½'
46'	31'	31'	21½'	4'	17½'
48'	20'	20'	21½'	4'	17½'

The dimensions for C, D, E, and F in the above tables are the limit for corresponding depth cover or over-burden "A," and all operations must be calculated to come safely within them.

For depths of cover or over-burden less than that given in the tables, the dimensions for C, D, E, and F would remain the same as for the least depth "A." in each table.

Thickness of coal vein has no effect on the stripping ability of these machines unless conditions other than those above considered are encountered.

A 360-ton steam shovel is used for stripping iron ore on the Mesabi Range in Minnesota. It is equipped with 6 to 8-cu. yd. dipper and has great reach. Fig. 56, taken from *Engineering and Contracting*, July 17, 1918, shows a cross-section of a single cut.

The loading track was laid in the surface of the ground as shown at A, and on this particular cross-section the great shovel had sufficient reach to push the accumulated spill from the cars clear of the further rail of the loading track.

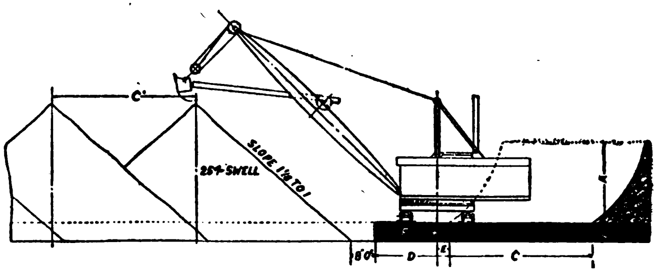


Fig. 55. Diagram Showing Reach of Large Stripping Shovels.

The divisions marked from 1 to 10 show the cuts that would have been necessary had the same cross-section been removed with a Model 91 shovel weighing 107 to 123 tons and having a 2½ to 4-yd. dipper, and the loading tracks for the different cuts are lettered from A to H. Track A is the loading track for the first

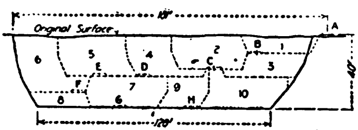


Fig. 56. Cross-Section of Cut Made by a Model 300 Shovel and Cuts Required to Remove Same Area with Model 91 Shovel.

cut, track B for the second cut, track C for the third and fourth, and so on.

Output of Large Stripping Shovel. *Engineering and Contracting*, Dec. 20, 1911, describes a large revolving shovel used for stripping 24 ft. of over burden from a bed of coal at Missionfield, Ill. The shovel was made by the Marion Steam Shovel Co. and had the following general dimensions:

Net shipping weight	135 tons.
Approximate working weight	146 tons.
Size of dipper, cu. yd.	3½
Length of boom between centers	65 ft.
Height of dump above rail (boom at 45 deg.)	45 ft.
Radius of cut at 30-ft. elevation	74 ft.
Radius of cut at bottom of pit	55 ft.
Center of dump from pivotal center	66 ft.
Radius at rear end of cab from pivotal center	31 ft. 6 in.

Hoisting engine (double)	12 x 14 in.
Swinging engine (double)	9 x 9 in.
Crowding engine (double)	8 x 8 in.
Boiler, locomotive type	60 in. x 17 ft.
Boiler designed for pressure of	150 lb.
Working pressure carried	125 lb.

The machine has been handling 1,600 cu. yd. per 8-hr. shift, and is being operated by men who have learned to operate it in this field. For several days the machine took out more than 2,000 yd. per day, and it is claimed by the builders that after the operators become expert the average output should equal this amount.

As to expense, the machine is operated by 1 engineman, 1 crane-

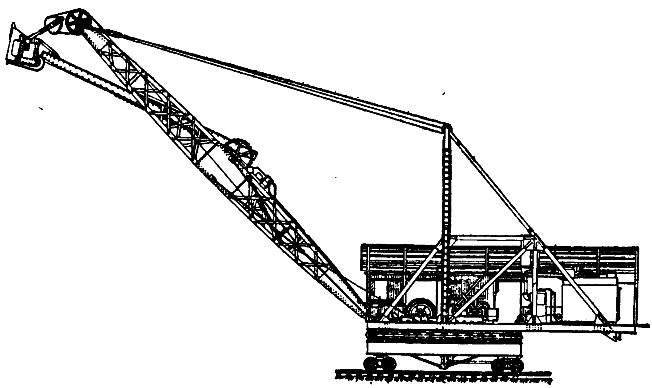


Fig. 57. Longitudinal Section of Revolving 150-Ton Marion Steam Shovel.

man, 1 fireman, 1 oiler or roustabout, 2 track men and 1 water and coal man, making a total crew of 7 men. The machine is equipped with feed-water heating and purifying system, which reduces the coal consumption very materially and it is operated daily on about 2 tons of coal.

Large Revolving Steam Shovel for Canal Construction. According to *Engineering and Contracting,* July 1, 1914, the large size revolving steam shovel, frequently used in coal stripping work, may be profitably employed in certain kinds of earth excavation. A machine of this type was used in connection with an inclined tipple in excavating Section 9 of Calumet Sag Canal, Ill. An interesting feature of this plant is its ability to excavate the entire prism of the canal at one cut (except the solid rock at the

bottom) and place the material in the spoil bank at one operation.

The Calumet Sag Canal at this point had a bottom width of 36 ft., a depth of cut of 36 ft. and slopes of 2 horizontal to 1 vertical,

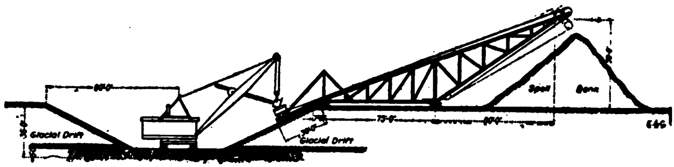


Fig. 58. Diagram Showing Arrangement of Revolving Steam Shovel and Steel Tipple for Canal Excavation.

tical, thus giving a top width of 180 ft. There were about 6 or 8 ft. of solid limestone in the bottom of the cut, the remainder being a glacial drift consisting of sand, gravel, boulders and clay.

Fig. 58 shows a typical cross-section of the canal prism and

Fig. 59. Marion Model 36 Revolving Shovel.

the general dimensions of the shovel and tipple. The steam shovel used was a Marion with a 3½-cu. yd. dipper and a 75-ft. boom. The extreme height of dump was 53 ft. above rails; extreme radius of dump 83 ft.; and the radius of cut at 34 ft.

above rails was 88 ft. The working weight of the shovel was 355,-000 lb. The tipple consisted of a cantilever incline of structural steel, which was carried by two parallel standard gage tracks on the canal berm with a hinged apron extending down the slope into the prism. On this incline were two standard gage tracks, which carried the two dump cars of 10-cu. yd. nominal capacity. These cars were operated independently of each other by a double cylinder double drum engine, with 10½- x 12-in. cylinders. A 100-hp. locomotive boiler furnished steam for the engine at 125 lb. pressure.

Fig. 60. American Railroad Ditcher Mounted on M. C. B. Trucks.

The method of operation was as follows: The car was lowered into the pit on the inclined apron and filled with two loads of the 3½-cu. yd. dipper, then hauled to the top of the incline where it ran onto a steel tipple frame, which was hinged to the top of the incline by a heavy shaft. The car was securely held on this frame by dogs which engage automatically. As the car reached its position on the tipple frame it released a latch which permitted the frame with the car to tip outward, thus dumping the load. A pendulum counterweight, attached to the tail of the tipple frame by a wire cable, prevented it from tipping too far, and returned it to its normal position after the load is dumped. The car was then lowered to the bottom of the incline by a foot brake. While one car was being dumped the second car was being loaded by the shovel; thus there were no delays waiting for cars.

The complete weight of the tipple with cars, engine, boiler, fuel and counterweights was approximately 300,000 lb., but as nearly all of this weight was carried by the rear truck, which is over 80 ft. from the edge of the slope, no trouble was experienced by caving of banks due to the weight of the machine.

Railroad Ditchers or Locomotive Crane Shovels. These are locomotive cranes with a shovel boom hinged to the center of the

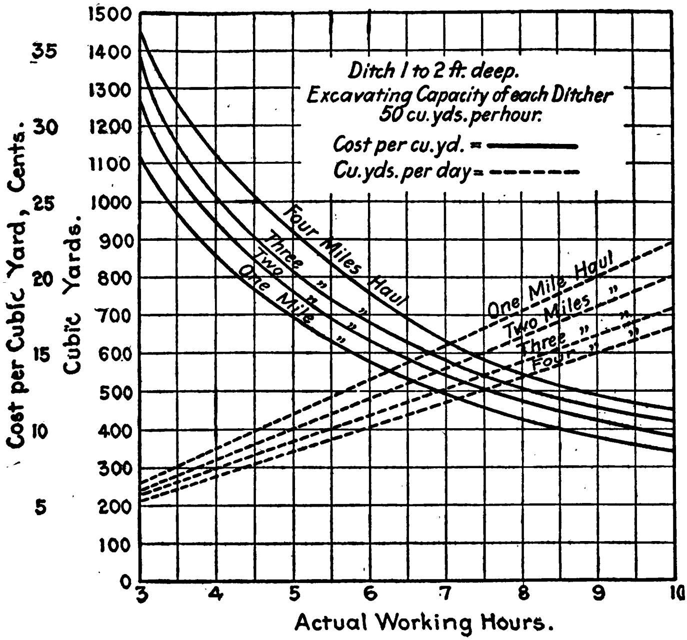


Fig. 61. Cost of Handling Material with a Double Ditcher Train.

mast. They are mounted on the flat cars they load, or on special trucks.

Single Track Revolving Shovels. These are built up to 40 tons in weight. They can load and dump at any angle which is of advantage in loading wagons but not at all necessary in loading cars on a parallel siding. For this reason most small revolving shovels are built with traction wheels.

Cost of Handling Material with Double Ditcher Train. In *Railway Maintenance Engineering* the following daily cost of operating a double ditcher train is given:

Two operators at $125 per month	$ 9.60
Two firemen	3.00
Interest on cars and ditchers	4.14
Depreciation on cars and ditchers	4.78
Oil, waste, etc.	1.00
Coal	5.00
Locomotive coal, etc.	15.00
Train crew	25.00
Repairs	2.00
Labor at $1.50 per day	6.00
	$75.52

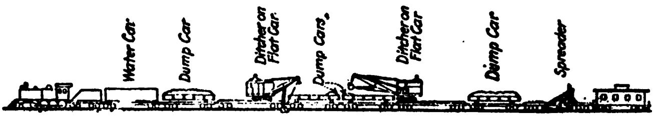


Fig. 62. Double Ditcher Train.

Conditions. Train — Four air dump cars, 80 cu. yd. capacity, two flat cars, one water car. Speed 20 miles per hr. Switch — 2 miles to run.

Based on the above figures and conditions the curves shown in Fig 61 are drawn.

A Revolving Shovel for a Brickyard. Wm. J. Spear gives the following relative to the work of a Vulcan No. 1 revolving steam shovel. The machine weighed 28 tons and was equipped with a ¾-yd. dipper. The work was the excavation of clay for brick manufacturing. The shovel was required to dig only 80 cu. yd. per day. For this outfit only one man operates the machine and he fires, acts as engineer and trips the bucket door. The shovel loaded one ¾-yd. dump car. This car was pulled to the brick-yard, an average distance of 700 ft., by a horse driven by a boy. The shovel loaded a second car while the first was being hauled to the brick yard. The shovel worked 10 hr. and used 600 lb. of coal per day. Water was furnished for the shovel from a tank that supplied the brick yard at a cost of about 7 ct. per day. One man was used to keep the track in condition and to clean up behind the shovel and around the cars. The total value of the outfit including cars was a little over $5,100 in 1908.

Small Revolving Shovels. The following is from Dana's "Handbook of Construction Plant." Revolving steam shovels on traction or railroad wheels are as follows:

Size No.	Shipping Weight	Dipper Capacity	Clear height of lift: Traction Wheels	Clear height of lift: R. R. Wheels	1914 Price
0	15 tons	½ cu. yd.	8′ 4″	9′	$3,750
1	24 tons	¾ cu. yd.	10′ 6″	11′ 3″	5,000
2	35 tons	1¼ cu. yd.	10′ 6″	11′ 6″	6,000

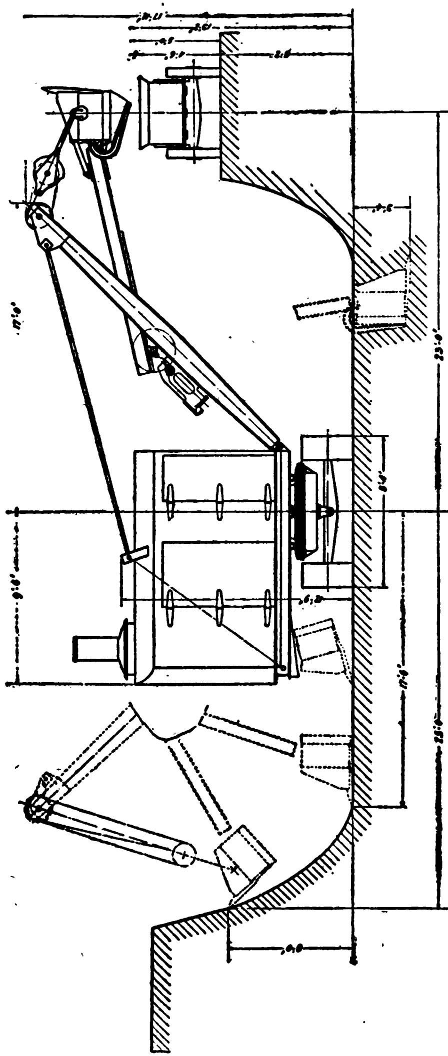


Fig. 63. Working Dimensions of Type B, Erie Shovel Made by the Ball Engine Co., Erie, Pa.

A No. 1 shovel of the above type was designed for general use on such work as real estate development. For excavating small sewers about 3 ft. wide and 10 to 16 ft. deep a very narrow dipper of ½-cu. yd. capacity and a dipper handle about 30 ft. long are used. In digging deep trenches in very sandy soil where many shifts from place to place are necessary, and where frequent curves are encountered, this shovel is not a suc-

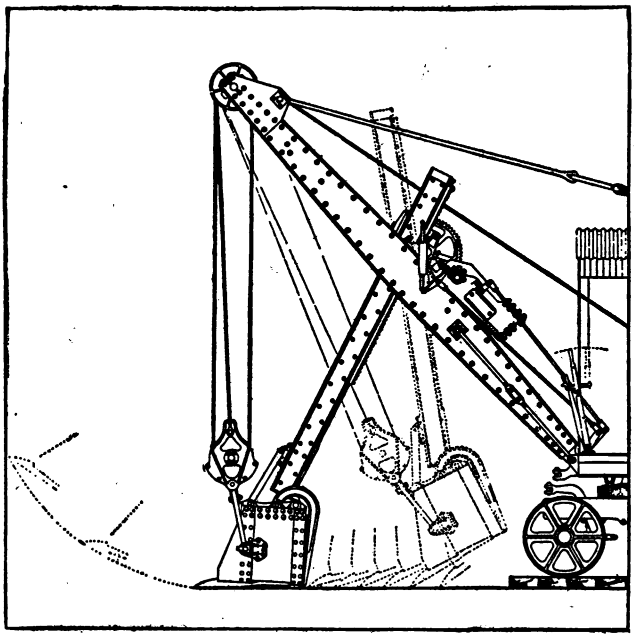


Fig. 64. Horizontal Crowding Motion of Erie Shovel, Made by the Ball Engine Co., Erie, Pa.

cess, but in firm earth where the sewer is long and continuous it is very efficient. 50 to 75 lin. ft. of trench 4 ft. wide and 12 ft. deep have been excavated and back-filled in 8 hr. by a machine of this type. One runner, one fireman, and two helpers form the crew. Platforms 16 ft. long of 12 x 12-in. timbers are necessary for the shovel to run on. These being built in four sections, each 4½ ft. wide, are carried forward by being hooked to the boom.

For excavating cellars the shovel has a standard dipper handle

with a ¾-yd. bank dipper, and for unloading cars or erecting steel, a crane boom 25 ft. long designed for use with a ½-cu. yd. clam shell or orange peel bucket, or a chain and hook. The price in 1914 was:

Shovel with ½ cu. yd. dipper and 30-ft dipper handle	$4,550
Standard dipper handle and ¾ cu. yd. dipper	500
Crane boom without bucket	475

A revolving shovel with a horizontal crowding engine, which enables it to excavate very shallow cuts economically, has independent engines for hoisting, swinging and crowding, and a vertical boiler.

Size No.	Shipping wt. (Tons)	Wt. equipped (Tons)	Mounting	Dipper capacity (cu. yd.)	1914 price	Rated capacity per hr. (cu. yd.)
0	13	15	Standard	⅝	$3,750	35—40
1	26	30	Gauge or	1	5,500	50—60
Special	20	20	Traction	⅞	4,750	40—50

A Mired Revolving Traction Shovel Can Lift Itself several inches off the ground so that planking can be placed under the wheels. This is done by dropping the dipper to the ground — as illustrated in *Engineering News*, Dec. 28, 1916 — and starting the crowding or boom engines, and forcing the dipper handle in an upward direction. As the dipper is placed flat on the ground it is impossible to force it below the surface. Consequently, when the boom or crowding engines are started, the shovel is forced to rise off the ground.

Cost of Excavating a Cellar with a Revolving Shovel. *According to Engineering and Contracting*, Apr. 15, 1908, in digging the foundation and cellar of a new building, in Minneapolis, Minn., the contractor used a steam shovel manufactured by the Browning Engineering Co.

This shovel was a locomotive crane with a dipper and dipper arm attached to the boom. One advantage of this shovel is that the boom angle is variable, being raised and lowered by a lever convenient to the engineer's hand. The dipper arm works on a shipper-shaft through the boom. This allows the dipper to dig both low down under the boom, and also high up on a bank. In digging this cellar, the shovel at first dumped the dirt directly into the wagon, but afterwards into a hopper, under which the wagons were driven and loaded. This hopper was roughly made, having no bottom, but it saved the wagon from being hit by the dipper, and also prevented dirt from being spilled off the wagon when loading. The hopper was picked up and moved about as needed by the crane.

Two men only were needed to operate this shovel, the engineer and fireman; the latter both fires and trips the dipper door. The cost of operating the shovel per day was as follows:

Engineman, 10 hr.	$3.00
Fireman, 10 hr.	2.00
Coal, ½ ton at $4	2.00
Oil and waste	0.30
Total operating cost per day	$7.30

The material in this cellar was hard stiff yellow clay, part of the time frozen from 6 to 10 in. The shovel averaged 400 cu. yd. per day. A further reason for this small output was a lack of wagons. Nevertheless the cost of loading the wagons was only 3 ct. per cu. yd. and including taking the shovel to another job 3 miles away the cost was only 5 ct. per cu. yd.

The Empire Engineering Co., of Montreal, Canada, moved one of these shovels over an ordinary wagon road a distance of two miles, under its own steam. Two sets of rails were used, the machine picking up the set in the rear and swinging them around in the front. The cost of moving was:

One engineman, 3 days	$ 9.00
3 laborers, 3 days at $1.60	14.40
Fuel	4.00
Oil and waste	.60
Team hauling water, 3 days	10.50
Total	$38.50

This makes a cost of $19.25 per mile, which is very cheap. The fact that the crane revolves cheapens the moving as well as much other work it does. In moving ahead in the cut the track is moved in the same manner. Then, too, when the machine has cut to the end of a row, it does not have to be turned like a shovel, but it revolves on its circle, and immediately begins digging.

In cellar excavating, after the earth is excavated, the dipper arm can be taken off, and the machine used as a crane for hoisting and erecting, or for pile driving, and for other purposes.

It can be equipped with a clam-shell bucket, and used for unloading sand and stone from cars, and also for unloading coal.

Steam Shovel Work at Springfield, Mass. Mr. Charles R. Gow, in a paper published in the *Journal of the Association of Engineering Societies* for December, 1910, gives some facts and figures concerning the operation of a No. 1 (24-ton) shovel of the revolving traction type. This shovel was assembled at the railroad siding and transported about 6½ miles over extremely bad roads. Plank track was necessary and the time occupied

was six days. The cost of unloading, assembling and transporting to work was $255.15. The depth of excavation varied from 1 to 17 ft. Part of the ground was fairly easy and the shovel excavated 300 to 500 cu. yd. per day, or at the rate of one loaded team per min. while actually working. The remainder of the excavation was in extremely hard ground with many large boulders and a shovel of 60 to 70 tons would have been more economical. The yardage fell to 100 cu. yd. per day. In the light cut of 1 to 2 ft. the dipper was crowded 7 ft. horizontally, thus filling it reasonably full.

The cost of steam shovel excavation at Springfield, Mass., 45,081 cu. yd. during 191 working days, or 235 cu. yd. per day, was:

Cost of delivering and installing shovel	$ 495.89
Foreman, supervising	1,668.00
Shovel operation, labor	2,118.81
Shovel operation, coal, oil, etc.	1,487.67
Total cost of operation	$ 3,606.48
Per cu. yd.	0.080
Repairs, labor	$ 315.57
Repairs, materials	631.14
Total cost of repairs	$ 946.71
Per cu. yd.	0.021
Depreciation on shovel	$ 1,758.16
Teaming excavated material	9,692.42
General expense, 12.9%	2,344.21
Grand total	$20,511.86
Total cost per cu. yd.	$0.455

The cost of repairs is exceptionally high on account of the very difficult nature of the work performed. Two new booms were supplied by the makers to take the place of broken ones, the second being of a special design. Several new dipper arms were required and the dipper teeth, chains and ropes were replaced every few weeks.

A No. 1 shovel, working in a cellar excavation about 13 ft. deep, loaded the material, which consisted of pliable clay with a few 12-in. boulders, into cars drawn by a horse along a single track. The costs were as follows:

Wages of engineman	$ 4.00
Wages of fireman	2.00
Wages of one foreman	3.00
Wages of three laborers	5.25
Coal	4.00
Oil, waste, etc.	1.00
Interest, depreciation and repairs (estimated)	5.30
Total	$24.55
Cubic yards per day	410
Cost per cu. yd.	6 ct.

The Thew Revolving Shovel is made in the following sizes:

Type	Weight tons	Dipper capacity, cu. yd.	Capacity cu. yd. per hr.	Coal, daily, lb. One man operation	Coal, daily, lb. Two man operation
A-0	15	⅝	40	600	1,000
0	18	⅝	40	600	1,000
A-1	24	⅞	60	1,000	1,500
1	32	1⅛-1⅜	80	1,500	2,000
2	35	¾*-1*	50*		
3	40	1¾	100		
4	55	1¼-1¾*	60*		

* In shale or hardpan.

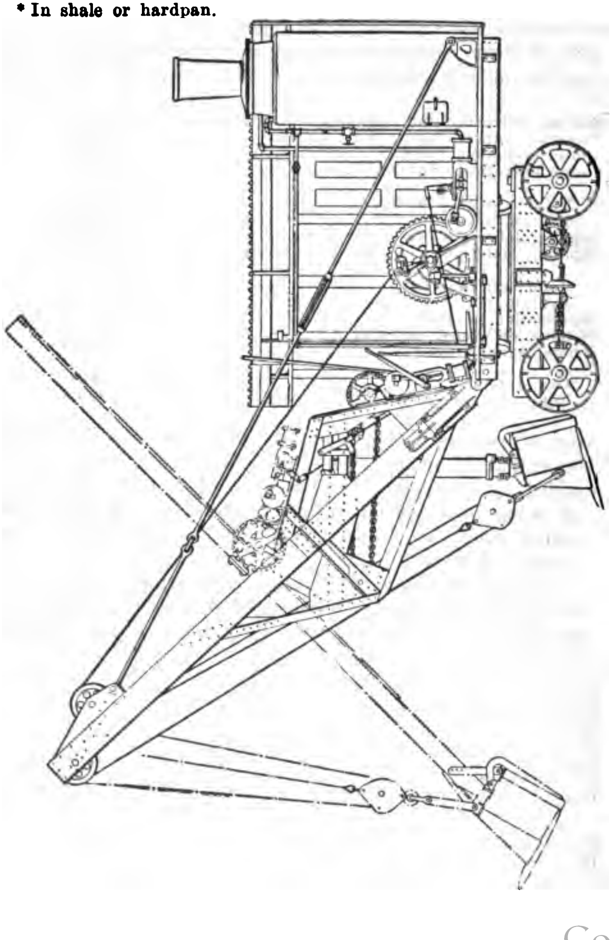


Fig. 65. Thew Shovel with Horizontal Crowding Mechanism and Alternate Equipment of Long Dipper Stick.

The shovel is furnished with two forms of boom equipment: the horizontal crowding motion which possesses definite advantages for shallow cut work; and the shipper shaft crowding mechanism and long dipper stick for use where maximum operating ranges are desired.

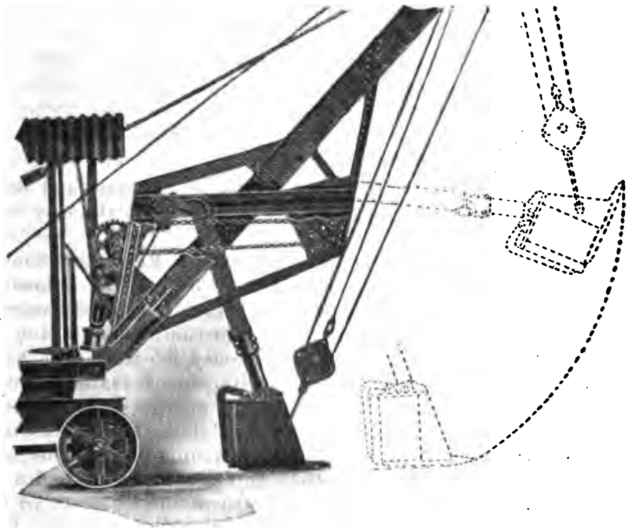


Fig. 66. Horizontal Crowding Motion of Thew Shovel.

Excavating a Street with a Revolving Shovel. According to *Engineering and Contracting*, June 9, 1909, a No. O (15-ton) Thew steam shovel was used for excavating about 18,000 cu. yd. for the repaving of Wentworth Ave. in Chicago. The cut ranged from 14 to 16 in. in depth.

The shovel loaded directly into wagons and had to wait on the wagons. This limited its output which, however, ran from 150 to 300 cu. yd. per 8-hr. day. The shovel was operated by a shovelman and a fireman. A snatch team was used at times to help wagons out of the pit. Altogether the working gang employed at the shovel was 8 men. About 1 ton of coal was burned per day.

The success of the shovel on this work was due to its full circle revolution and horizontal crowding motion.

Operating a Revolving Shovel in Brick Clay. *Engineering and Contracting*, April 12, 1911, gives the following:

The Macon Brick Co., of Macon, Ga., used a 25-ton Vulcan re-

volving shovel for excavating about 100 cu. yd. of brick clay per day.

The shovel is equipped with a ¾-yd. dipper. The dipper handle is 12 ft. long and will dump 12½ ft. above the rail. It will clear a floor 32 ft. wide and make a cut 40 ft. wide in a 6-ft. bank. It swings through a full circle. The Macon Brick Co. employed the following men in their work:

1 engineer, per day	$3.00
1 helper, per day	1.25
2 trackmen, per day	2.50
Oil, waste and repairs, per day	0.50
Coal, 600 lb. per day	1.05
Total labor and fuel	$8.30

The shovel is in operation only a part of the time and could furnish twice as much clay from the 8-ft. bank if the clay were needed.

Excavating a Building Foundation with a Revolving Shovel. *Engineering and Contracting*, July 30, 1913, gives the following:

In excavating for the foundations of a reinforced concrete building in Boston, the Aberthaw Construction Co. of Boston obtained cost figures which are low for a city job where the hauls to dumps averaged over a mile. The site was excavated to 10 ft. deep; the digging was good; there were no rocks, the material being mostly cinders. A ⅝-cu. yd. Thew steam shovel was used and the carting was done by 2-horse end dumping wagons each of a capacity of 2 cu. yd.; in other words, each wagon had a capacity of three shovelsful. The total cost of the 6,976 cu. yd. excavated, including excavating, labor, teaming and dumping, lumber for runs, and all fuel and other expense in connection with the shovel, was 66.8 ct. per cu. yd. The itemized figures are presented below:

Excavating:	
Shovel, 25 days	$ 300
1 fireman, 25 days at $18 per week 1 engineer, 25 days at $37 per week	229
1 foreman, 25 days 6 hr. at $5	83
2 laborers trimming around shovel at $2	100
Preparatory to shovel and other labor, during shoveling, 411 men at $2; estimated 10% at dump	740
Miscellaneous laborers	37
	$1,489

Excavating 6,976 yards, 21.3 ct. per cu. yd; does not include runway.

Hauling and Dumping:	
481 teams at $6	$2,886
Foreman, 32 days at 10 hr. at $5	176
Laborers	82
Lumber for runs	31
	$3,175

Teaming and dumping 6,976 yd. cost 45½ ct. per cu. yd.

Total cost per yd. of excavating, teaming and dumping was 66.8 ct.

Revolving Shovel Working Excavating Macadam. James L. Kehoe, describing a pavement job in Newburgh, N. Y., in *Engineering and Contracting*, July 8, 1914, says:

Old macadam was encountered on the section of street having no car tracks, on the remainder, gravel and hardpan. Owing to the short time allowed to complete the work, together with the hard cutting it was deemed advisable to use a steam shovel.

On the old macadam section a No. 0 (15-ton) Thew steam shovel of the traction type was placed in the center of the street loading from both sides into 1½ and 2-cu. yd. dump wagons. Cuts averaged from 12 to 18 in. deep at the center line, and 4 to 6 in. at the curb. A level cut to grade was made by the shovel across the street for a width of 25 ft.

The material near the curb was piled in front of shovel by means of buck scrapers working evenings, or before starting in the morning. In this way the shovel always had enough material to load all teams for the first trip without loss of time.

Owing to the shallow cutting the shovel was moved up about every 5 ft. and when there were no teams to load the shovel kept crowding ahead piling material. The average loading time for a 1½-cu. yd. wagon was 1 min. Fifteen teams averaged 250 cu. yd. per day of material hauled from the shovel.

On the hardpan and gravel section the shovel was placed between the trolley tracks and curb, loading across the tracks into side dumping trolley cars and dump wagons. On account of the boom on the shovel having only a few inches clearance from the trolley feed wire, two extra men were employed to raise and lower the wire, using notched poles. As the traction company maintained a 25 min. schedule some time was lost by the shovel on account of the wire being raised and lowered so often. Earth between the tracks was plowed with a heavy rooter plow hauled by a trolley car, the shoe on the plow being set so that the point just cleared the ties. This loosened material was shoveled to one side by hand and left for the shovel to load. On this section some hard shale was found about 6 in. below grade, but the shovel had no trouble cutting through it. Many predictions of failure were heard from the "sidewalk inspectors," but after the shovel had scooped several dippers of macadam they were convinced that it would excavate the entire street. Water for the shovel was piped in the same manner as for the mixer, a ¾-in. T being placed every 50 ft.

A fine grading (or trimming) gang of ten men followed closely

behind the shovel grading to stakes set from a grade line stretched from curb to curb. About 600 sq. yd. of fine grading was the average per day.

Street Grading with a Revolving Shovel in Los Angeles. The *Excavating Engineer*, June, 1914, describes a grading job on which, despite the shallow cutting, a small revolving shovel was used to splendid advantage. The total yardage amounted to 23,016 cu. yd., bank measure, which was handled between March 10th and April 25th, 39½ days in all, including Sundays.

The shovel, which was an 18-B Bucyrus, equipped with a ⅞-yd dipper, burned fuel oil. 12 tanks, or 10,080 gallons were consumed during this period. The oil cost $12 a tank.

Throughout the entire job, Sundays were regularly devoted to washing out the boiler, cleaning the flues and making sundry repairs, which, doubtless accounts to a large degree for the regularity of the output. Although the greater part of the material was classified as earth, there was over 7,000 yd. of rock and sandstone, besides 2,300 yd. of hard adobe clay, which, naturally cut down the capacity of the shovel considerably.

The following data are given for the performance of this shovel:

Total yardage (bank measure)	23,016 cu. yd.
Total time under steam	34½ days.
Lost time including delays for moving, blasting, repairs, etc.	23½ hr.
Average yardage per hr. working	67.8 cu. yd.
Average yardage per hr. under steam including delays	63.4 cu. yd.
Maximum output per 11-hr. day bank measure	735 wagons 1,000 cu. yd.
Cost of labor and fuel	3.3 ct. per cu. yd.

The best week's output was perhaps the first week in April, the record of which shows that 4,649 wagons were loaded with 6,300 cu. yd. of material in 75 working hr., giving an average of 84 cu. yd. per hr. including delays.

It might be interesting to note that after the completion of this job, the shovel was moved a distance of about 7 miles in 2½ hr. by the use of two five-ton automobile trucks. The propelling was done entirely by the trucks at a cost of $2.25 per hr. per truck.

Basement Excavation with Revolving Shovel. Professor A. B. McDaniel, in *Engineering Record*, June 16, 1915, describes methods employed and gives detailed costs of excavation for two buildings. The following is an abstract of his article:

Case 1 — Steam-Shovel Excavation. A steam shovel was used in excavating for the first building, which is being constructed for the Dennison Manufacturing Company, of South Farmingham, Mass. The building is rectangular in form, 70 ft. x 159 ft. 5 in.,

with two projecting stair towers and a toilet tower. The general plan of the building is shown in Fig. 67.

The soil excavated was a fine, clean, siliceous sand, in beds from 3 to 7 ft. in depth, and separated by strata of yellow clay, of a depth of 1 or 2 ft. The excavation was carried down to a gravel subsoil, upon which the footings were placed. The depth of excavation varied from 8.2 to 10.5 ft.

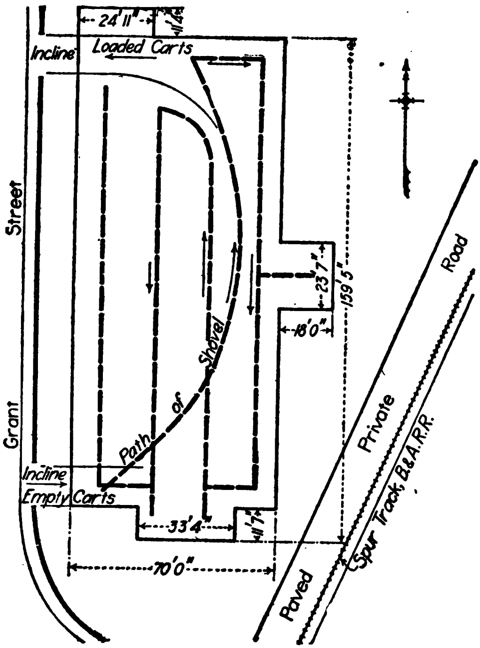


Fig. 67. Path of Steam Shovel.

The excavated material was used to fill up two low, swampy tracts of land which were located about 1/3 mile from the site of the building.

Method of Excavation. A new Thew Automatic revolving steam shovel, type O (18-ton), equipped with a 5/8-yd. dipper, was used for the bulk of the excavation. The manufacturers furnished an expert engineer who set up and operated the machine for several days, during which time he broke in a "green

hand" as the runner. The latter operated the shovel without aid or supervision during the last ten days of the work.

The shovel began operations near the southwest corner of the building plot, and excavated a cut about 15 ft. wide on a descending grade of about 10%. As the shovel approached the northeast corner of the plot it reached the finished grade, which was about 10.5 ft. below the original ground surface at this point.

Path of Shovel. The path of the shovel is shown by the dash line in Fig. 67. The east side of the excavation was completed first, as it was desirable to construct the footings and erect the basement column forms along this side, adjacent to the mixer plant and pouring tower, as early as possible. While the shovel was excavating in a southerly direction along the east side, a slip scraper was used to cut an inclined road from the north gate on Grant Street, along the north side of the plot, and curving and descending on a grade of about 6% to the bottom of the excavation near the north end of the toilet tower. After the shovel had started on its second trip along the plot the wagons came in at the south gate on Grant Street, passed down the incline along the south side of the plot, around the east side of the shovel, where they loaded and passed up the north incline and out the north gate on Grant Street, to the dump.

Support for Shovel. On account of the loose character of the soil and the inflow of water when the excavation reached grade, it was necessary to support the shovel on planking. A movable, sectional, platform was built of 4 x 8-in. timbers, bolted together to form sections 3 ft. wide and 12 ft. long. Four of these sections were used on straight stretches, and two triangular-shaped sections, half the size of the rectangular sections, were employed on the turns. Near the center of both ends of each section was placed a heavy iron eye by means of which the section could be shifted around with a chain attached to the dipper arm.

Neglecting time lost through breaks in machinery, inclement weather, etc., the shovel was excavating about 60% of the working time. Special effort was made to keep the shovel always supplied with wagons to load, and very little delay was occasioned from waiting for teams. From two to three shovelfuls were required to load each wagon to an average capacity of about 1⅛ cu. yd. (loose measurement). On account of the looseness of the material, the average shovelful was about ½ cu. yd. Based on a large number of observations, the average time to make a complete dipper swing was 26 sec. and the minimum time was 18 sec. The average time to load a wagon, with three swings, was 1 min. 46 sec., and the minimum time was 1 min. 21 sec.

Labor and Fuel Costs. The labor crew consisted of one foreman, one engineman, one fireman and two pitmen, or laborers. Following is a schedule of labor expenses per day of 9 hr.:

1 foreman at $6 per day	$ 6.00
1 engineman at $0.45 per hr.	4.05
1 fireman at $0.30 per hr.	2.70
2 pitmen at $2.03 per day	4.06
Total labor cost per 9-hr. day	$16.81

Water was supplied to the boilers through a rubber hose. Coal and coke were hauled thrice daily from a pile on the east side of the excavation and shoveled into a large wooden bunker built on the rear of the machine. The fuel cost for the operation of the shovel for 17 days was as follows:

7 tons coal at $6.25	$43.75
1 ton coke at $6.75	6.75
Total cost of fuel	$50.50

The excavation was leveled up and made closely to grade by the use of a slip scraper, which was attached by a chain to the dipper handle. This work was done as far as practicable, during the short periods of waiting for wagons, at the beginning and end of each half day's work.

The hauling away of the excavated material was done by rear dump carts hauled by two horses. These carts had a rated capacity of 1 cu. yd., and were generally filled by three dipperfuls to a capacity of 1⅛ cu. yd. Care was taken to place the bulk of the load over the rear axle, so as to facilitate the dumping. From 8 to 14 teams were used and the latter number proved to give the most efficient operation of the shovel. The average haul was 1,800 ft. The teams were run continuously in a circuit, and except for a short distance (about 200 ft.) the loaded teams were not allowed to pass the unloaded teams. Bunching of the teams was largely eliminated by careful supervision of the dumping and the movement of the carts along the road. A decided tendency to lag was noticed each day during the last hour of work. Some drivers would stop work during the last half hour if they thought that another load would take until after 5 o'clock to dump. In the morning several teams were usually late in arriving at the shovel for the first load. In order to eliminate these time losses, at the end of the first week's work a bonus of 25 ct. was offered to each driver who made 24 trips per day. During the first day's work under the bonus plan one man made 25 trips, four men made 24 trips and seven others raised their previous day's record by one trip. After a study of

this result a bonus schedule was established as follows: 25 ct. per day per man for 24 trips; 40 ct. per day per man for 25 trips; 50 ct. per day per man for 26 trips.

The average number of trips per day per team for the last full day's work (July 22) was nearly 25. Several teams made 26 trips per day.

Time Records. A timekeeper stationed near the building site kept a record of the time that each team entered the south gate and left the north gate. This record served to show the character and length of delays in the yard, such as loss of time in pulling up to shovel, and delay at the shovel. The dump foreman kept

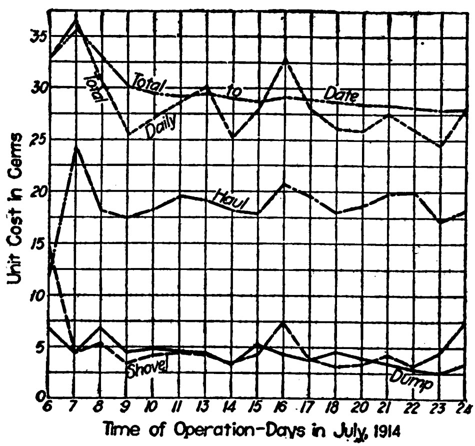


Fig. 68. Shovel Haul and Dump Costs.

a record of the time of arrival of each team at the dump, and also of any delay in dumping and leaving the dump. The watches of the yard timekeeper and the dump foreman were synchronized daily. At the end of each day's work, the two records were compared and a study was made to determine the number, character, length and cause of all delays, the inefficient teams, the proper size and distribution of the load in the carts for efficient hauling and dumping.

The average length of haul was 1,800 ft. The average time to make a round trip was about 21.5 min., and the minimum time was 15 min. Each of the two dump sites was a low, swampy basin which it was desired to grade up to the level of the adjacent streets. The fill at each site was made at two points

simultaneously and was built out from firm soil by rear-dumping from platforms. These platforms were made of several sections of 2 x 12-in. planks 16 ft. long, cleated together on the under side. As the dump was carried out the sections of platform were moved ahead. Railroad ties were used as dumping blocks. To facilitate the dumping, especially when the sand and clay was wet and sticky, the drivers greased the main axle trunnions and salted the inside surfaces of the carts each morning before starting work. The depth of fill varied from 0 to 7 ft.

The labor used in operating the dump during the first week consisted of a foreman, a sub-foreman and four laborers. This force was gradually reduced to a foreman and three laborers during the last four days of work. Thus an economy of 30% was effected during the time that an increased output of 16% occurred. Fig. 68 and the following table give a summary of the total daily and the unit costs for the various divisions of the work and the job as a whole.

	Total cost	Cost per cu. yd.
Labor at shovel	$ 262.31	$0.0515
Labor at dump	236.53	0.0464
Labor on roads and inclines	18.90	0.0037
Teams and hauling	1,058.59	0.2078
Superintendence, etc.	150.00	0.0294
Lumber for inclines, platforms, etc.	250.00	0.0491
Unloading, setting up, dismantling and loading shovel	179.05	0.0351
Rental of shovel	390.00	0.0765
Coal, oil, waste, repairs, etc.	66.60	0.0131
Total (17 days)	$2,611.98	$0.5126

* Based on total computed excavation (place measurement) of 5,095 cu. yd.

A somewhat similar building excavating job is described by Professor McDaniel in this same article. Wheel and drag scrapers were used, also dump carts loaded by hand. The final average unit cost was $1.10 per cu. yd.

Cost with a Thew Shovel on Street Work. A description of the work of 3 revolving shovels, one with a 5/8-yd. dipper and two with 3/4-yd. dippers, used in street grading in Minneapolis during 1914, is given by Prof. A. B. McDaniel, in *Engineering Record,* July 31, 1915. The material excavated was ordinary earth and underlying glacial clay. On ordinary grading work, with an average haul of 300 ft., the cost of excavation, hauling, and dumping, was 15 ct. per cu. yd. with 1½-yd. wagons, and 11 ct. per cu. yd. with cars.

An 18-ton revolving shovel (Thew) with a 5/8-yd. dipper was used in excavating hard, dense clay of the street surface. This material was mixed with boulders. The use of a heavy pavement

plow had been found to be impracticable. The average cut was 1 ft. The excavated earth was dumped into 1½-yd. bottom-dump wagons. The cost of excavation under average working conditions per 8-hr. day is given below. An average hourly excavation of 31.25 cu. yd. was obtained. The cost does not include the cost of hauling the material to the dump or of taking care of it after it has reached there.

1 engineman	$ 6.00
1 fireman	2.50
2 laborers, at $2.50	5.00
Total labor cost	$13.50
Coal, ½ ton, at $6	$ 3.00
Oil, grease and waste	0.15
Repairs and overhead charges	1.05
Total fuel cost	$ 4.20
Total cost of excavating 250 cu. yd.	$17.70
Cost of excavation of 1 cu. yd.	$0.07

Another Thew revolving shovel equipped with a ⅝-yd. dipper was used for street grading in Lexington, Kentucky. The material excavated was a packed clay and loam surface. In 60 hr., exclusive of the time lost because of delays and causes foreign to the work, 1,445 cu. yd., "place measure," were excavated. The depth of the cut was 10 in. The total length of excavation is 1,788 ft. The number of teams used was 10. The average excavation per hr. was 24 cu. yd.

In Ogden, Utah, another Thew revolving shovel, with a ⅝-yd. dipper was used in street pavement work. The contract included the removal of 22,500 sq. yd. of concrete pavement, 10 in. thick. The shovel removed a section of concrete 600 ft. long and 20 ft. wide each working day. The loading of teams was delayed on account of the frequent passage of street cars. The cost of this work was:

1 foreman	$ 4.50
1 engineman	7.00
1 fireman	3.00
2 pitmen, at $2	4.00
5 teams and drivers, at $5	25.00
Total labor cost	$43.50
Cost of excavation per sq. yd.	$0.03
Cost of excavation per cu. yd.	0.11

In a fourth case, a Thew revolving shovel, equipped with a ¾-yd. dipper, was used in 1912 for the removal of macadam surface on a section of a street in St. Louis. The street was 28 ft. wide and the macadam was 13 to 18 in. thick. The total

excavation was 2,915 cu. yd. loose measure, made in a total operating time of 94 hr., an average of 7.8 hr. per day for 12 days. The average excavation was 31.9 cu. yd. per hr. of actual working time.

The following is the output to be expected of a revolving shovel in shallow excavation. This table is based on the use of an 18-ton revolving shovel, equipped with a ⅝-yd. dipper, efficiently operated. The outputs are based on 62 observations under the conditions named.

Depth of cut in in.	Classification of material — Loose earth Yardage	Packed earth Yardage	Hardpan Yardage	Pavements Yardage
18	360	280	225	300
12	300	240	175	250
9	250	200	150	200
6	200	150	100	150

Cost of Revolving Shovel Work in Road Grading, California. J. E. Bonersmith, in *Engineering and Contracting*, July 19, 1916, gives the following:

The work described was on the California State Highway between Tormey and Eckley in Contra Costa County, California, and was done in 1915. The road graded was four miles in length and contained 72,000 cu. yd. of excavation through a rather rough country. The material consisted of earth, soft and hard shale.

The method of work was as follows: After the culverts were constructed, two fresno gangs (each gang having a six-horse plow and from four to six fresnos) were started and made the fill over the culverts; also moved the dirt in all cuts where the hauls were 200 ft. and less. A Model 31 Marion Revolving Shovel (28-tons shipping weight, 1 cu. yd. dipper) followed the fresno gangs and loaded all the material that had to be hauled into dump wagons. The number of wagons varied from six to twelve. Behind the steam shovel, a small fresno with four muckers did all the finishing work.

The road was graded to a width of 21 ft. and through the thorough cuts the shovel had to turn through a full 180°. On this work, the average output of the shovel for an 8-hr. day was 375 cu. yd., as there was considerable loss of time in spotting the wagons; but where the dipper was swinging only through 90°, it handled 510 cu. yd. The local water was the cause of some delay, and since the water is a very serious question in the cost of equipment on any job, we now make it a rule to have the water analyzed and the proper boiler compound on hand before the shovel starts to work.

Rentals per day: Horses rented to job at $1.25 per working day; fresnos, wagons, etc., at $0.25 per working day; wagon

and fresno driver at $2.50 per day; Marion steam shovel, including fuel, runner, etc., $50 per day. These costs of equipment are used on all our work, as we have found from many years of experience that it is the only way we can arrive at a true cost. Take the shovel as an example; its rental is based on the following charges:

First cost, $8,200; life of shovel, 1,000 working days in six years; cost per day	$ 8.25
6% interest on $8,200 for three years, $1,476; interest per day	1.48
Repairs (when the shovel is broken down the engineers', firemen, etc., time is charged to repairs), per day	2.00
Freight, knocking down, etc. (this cost was arrived at by cost kept on another shovel), per day	3.00
Fuel, ¾ ton of coal per working day at $12 per ton	9.00
Water wagon with four horses and driver, per day	7.75
Water and oil, per day	.85
Engineer, per day	6.75
Fireman, per day	3.00
Two pitmen at $2.50 per day	5.00
Incidentals	2.92
Total cost per day	$50.00

Following is the total cost of the above mentioned grading of the State Highway between Tormey and Eckley, 72,000 cu. yd.:

Horses, 8,756 days at $1.25 per day	$10,945.00
Equipment, 1,842 days at 25 ct. per day	460.50
Driver labor, 1,842 days at $2.50 per day	4,605.00
Steam shovel, 104 days at $50 per day	5,200.00
Foreman, 120 days at $5 per day	600.00
Timekeeper, 4 months at $75 per month	300.00
Muckers and slopers, 500 days at $2.25 per day	1,125.00
Muckers, slopers, etc., 212 days at $2.50 per day	530.00
Purchases (picks, shovels, lanterns, oils, etc.)	182.60
Insurance	280.00
Total cost	$24,248.10
Cost per cu. yd.	33.7 ct.

Revolving Shovel on Road in Oregon. In *Engineering and Contracting*, June 7, 1916, N. J. Chapman describes a notable example of road grading. The work was in Klamath County, Oregon, overlooking Klamath Lake, and was part of a 9-mile road, about 7½ miles of which were light earthwork, which was performed with teams and scrapers. The remaining 1½ miles were steam shovel sidehill cutting around Rattle Snake Point and having a grade of about 3%. The cut was made with a side slope of 1 on 1½ and wide enough to give a 20-ft. roadway outside the ditch. This cutting gave a yardage per lineal foot of road of from 5 to 8½ cu. yd. The material consisted of loose boulders, which had slid down the mountain side, overlying in places cemented gravel, cinders, chalk rock and solid ledge. All had to be blasted.

The general method of work was to blast and excavate with steam shovel, casting the spoil down hill to form embankment. A 4-in. duplex pump operated by a 6-hp. Fairbanks-Morse gasoline engine was set 12 ft. above lake level. A 2½-in. suction pipe was used. The delivery pipe was 2 in. in diameter and 650 ft. long and delivered up hill to a tank located above all parts of the work. From this storage tank the water was piped to the steam shovel and camp. To provide the daily supply the pump had to be operated about one hour. For the drilling, a 10-hp. Sullivan air compressor driven by a 6-hp. Fairbanks-Morse gasoline engine was mounted on skids back of the shovel and the air pipe ahead to two Little Giant rock drills. One team could move the compressor plant ahead 1,000 ft. and set it up ready for work in 30 min.

The steam shovel was a No. 14B (20-ton) revolving Bucyrus. The crew worked on and about the shovel consisted of an engineman, a fireman, a pitman and a wood and water man. The shovel graded 7,884 lin. ft. at an average rate of about 60 ft. per day. The total operating cost, including labor, oil, repairs, fuel and lights, but excluding interest, depreciation and overhead charges, was $6,480, or about 12 ct. per cu. yd. Finishing behind the shovel was done by hand and it usually took three men per day to finish up in good shape. The cost of finishing was 3 ct. per cu. yd., based on the total yardage handled by the shovel.

Blasting ahead of the shovel cost more than solid rock would have cost, because the drills could not be used in all material. In many places "coyote" holes 6 in. in diameter and 20 ft. into the bank had to be drilled by hand. Also care had to be exercised in blasting to protect the railway tracks downhill from the grading. The crew ahead of the shovel consisted of from 6 to 12 men, and one powerman, who did all the loading and firing. A 60-hole battery was used for firing. The blasting cost, including labor, powder, exploders and battery, $11,882 or about 22 ct. per cu. yd. based on the total steam shovel yardage.

Cost of Street Grading with Revolving Shovel, in Minneapolis. Fred T. Paul, in *Engineering and Contracting*, June 7, 1916, describes work done by force account in 1915 under the City Engineer's Department. The material moved was a conglomerate with a medium fine sand predominating. The cut was from 2 to 15 ft. deep, 70 to 80 ft. wide, and about 3,500 ft. long. A Marion-Osgood No. 18, ¾-cu. yd. traction steam shovel placed the material in ordinary 1½-cu. yd. dump wagons, and these in turn deposited it in the fills on the street, making an average haul for the job of 1,000 ft.

The work was started June 12 and finished Aug. 20, covering

a period of 55 full working days of eight hours each, and five part days. On these part days, little, if any, dirt was moved, but the engineer, foreman, fireman, watchman and timekeeper received full time — while the laborers and teams were given only part time. A total of 21,500 cu. yd. of material were handled in the 55 full days, making an average day's output of 391 cu. yd. The maximum was reached during five days in the heaviest cut when 611 cu. yd. per day was moved.

The total material cost of the job was as follows:

27.45 tons of soft coal at $5.05 per ton	$ 138.62
50 gal. steam cylinder oil at $0.294 per gal.	14.70
Blacksmith repairs	17.64
New shovel parts	.82
Miscellaneous, including waste, packing, hose, grease, etc.	27.78
	$ 199.56

The average daily payroll was as follows:

1 foreman at $4 per day	$ 4.00
1 engineman at $6 per day	6.00
1 fireman at $2.50 per day	2.50
1-20th timekeeper at $4 per day	.20
1 watchman at $2.50 per day	2.50
2 laborers on dump at $2.50 per day each	5.00
2 laborers in pit at $2.50 per day each	5.00
1 laborer on coal and water at $2.50 per day	2.50
6 laborers straightening and leveling up at $2.50 per day each	15.00
7 teams on dump wagons at $5 per day each	35.00
Total average daily payroll	$ 77.70
Grand total payroll for sixty days	$4,553.61
Total material as above	199.56
Interest and depreciation on plant	70.00
	$4,823.17

Distribution and Unit Costs

General —	Amount
Foreman, 60 days at $4	$ 240.00
1-20th timekeeper, 60 days at 20 ct.	12.00
Total general	$ 252.00
Per cu. yd.	$0.012

Excavating and Placing Material in Wagons

Labor —	
Engineer, 60 days at $6	$ 360.00
Fireman, 60 days at $2.50	150.00
Watchman, 60 days at $2.50	150.00
2 pit laborers, 58 days at $5	290.00
Laborer on coal and water, 58¼ days at $2.50	145.61
6 laborers on cleanup, 58 days at $15	870.00
Total labor	$1,965.61
Per cu. yd.	$0.091
Material and supplies as above	$ 199.56
Interest and depreciation on plant, 10½% on $4,000 for 60 days	70.00
	$2,235.17
Per cu. yd.	$0.104

Hauling, Including Placing in Dump

7 teams, 58½ days at $35	$2,046.00
2 laborers, 58 days at $5	290.00
	$2,336.00
Per cu. yd.	$0.109
Grand totals	$4,823.17
Per cu. yd.	$0.224

Based on the total cost of moving 21,500 cu. yd. an average distance of 1,000 ft., the cost per cubic yard hauled 100 ft. would be .022. However, the actual hauling cost per cubic yard per 100 ft. was only .011.

Revolving Shovel on Street Railway. Costs are given by Tirrell J. Ferrenz, in *Engineering and Contracting*, Oct. 18, 1916, as follows:

The Chicago Surface Lines build on the average from 50 to 60 miles of single track per year. Inasmuch as the city of Chicago embraces over 200 square miles of territory within its corporate limits, widely divergent soil conditions are encountered in this work. These include a large amount of stiff clay and sandy soil, together with considerable swamp land and in some instances of outcropping rock. It is the practice, wherever conditions permit, to employ a steam or electric shovel in excavating to subgrade for the track structure.

The standard type of construction, as approved by the Board of Supervising Engineers, provides for depths of 21⅝ in. and 23⅝ in. from the street grade to track foundation, the width of cut commonly being 18 ft. 2 in. for double track.

The following results were obtained by a detail time-study of excavation on West 51st St., between Leavitt St. and Central Park Av., a distance of 1¾ miles:

Depth of cut, average	26 in.
Width of trench	18 ft. 2 in.
Kind of material	Stiff clay
Type of shovel (18-ton)	Thew steam shovel
Capacity of shovel	⅝ cu. yd.

Swell of Broken Ground. The quantity of material in place was obtained by taking levels at various points and computing the yardage for each 10-ft. section. Loose earth was removed by wagons which were loaded full each trip.

Lineal feet excavated on test	230
Total place measurement, cu. yd.	230
Number of loads	221
Capacity per load, cu. yd.	2
Total loose material, cu. yd.	442
Swell of broken ground, per cent.	34

Time Excavating and Loading:

Wagon in position for loading, min.	0.25
Time for loading, min.	1.52

Getting under way, min.	0.20
Moving up shovel, min.	0.20
Minimum time per load, min.	2.17
Average time per load, including all stops, delays, etc., min.	2.52
Average number of loads per 10-hr. day	238
Cubic yards loose material loaded per 10-hr. day	476
Cubic yards in place loaded per 10-hr. day	356
Lineal feet excavated per 10-hr. day	243
Cubic yards in place per lineal foot	1.46

Time Hauling. Hauling was done by a teaming contractor under a general agreement covering the removal of all excavated material within the limits of a specified territory. Hauling by wagon over common, fairly dry, unpaved streets required 0.5 min. per 100 ft.

Rate per 100 ft., incl. stops, lost time, etc., min.	1.085
Average length of haul, ft.	800
Hauling time per trip, min.	17.36
Total time per trip, incl. loading, min.	19.88
Number trips per team per 10-hr. day	30
Number teams required	8

Labor Excavating and Loading:

1 engineman at 75 ct. per hr.	$ 0.75
1 fireman at 34 ct. per hr.	0.34
10 laborers at 22½ ct. per hr.	2.25
Per hour	$ 3.34
Total per 10-hr. day	33.40

The gang of ten laborers was used in moving shovel platform, furnishing coal and water for shovel, dressing up ditch and loading wagons. One shovel watchman was employed at $2.50 per day. His duties consisted in watching shovel and keeping up fire at night. A lunch period of 30 min. was allowed at noon.

Cost of Supplies for Shovel:

3 tons Pocahontas coal at $5.25	$15.75
5 gal. cylinder oil at $0.40	2.00
3½ gal. engine oil at $0.275	0.96
3 lb. colored waste at $0.07	0.21
1½ lb. white waste at $0.105	0.16
2 lb. cup grease at $0.08	0.16
Total cost per week of six days	$19.24
Cost per day	3.21

Summary of Costs:

	Per 10-hr. day	Per cu. yd. in place
Excavating and loading	$33.40	$0.094
Watching shovel	2.50	0.007
Supplies for shovel	3.21	0.009
Total	$39.11	$0.110

Revolving Shovel Work on Roads in Utah. According to ***Engineering and Contracting***, Nov. 6, 1918, the State Roads Com-

mission of Utah is employing steam shovels on heavy cuts and sidehill work in connection with road construction projects. On one job in Weber Canyon, near Henefer, a 20-ton Bucyrus Model 18-B, working on sidehill cuts for roadway, moved about 400 cu. yd. per 8-hr. shift for several days. The material was about 35% earth and 65% boulders, ranging from 6 in. to 3 ft. in diameter or even larger. Some of the larger boulders were broken with blasting powder ahead of the shovel. The total operating expenses per 8-hr. shift were as follows:

Team and wagon	$ 6.00
Steam shovel engineman	6.00
3 men at $4	12.00
Field engineer	6.00
Coal	4.00
Oil	1.00
Total per day	$35.00

Taking into account the time lost for occasional repairs, a unit price of 10 ct. per cu. yd. was obtained on the greater part of this work.

Steam shovel work in Willow Creek on the Castle Gate-Duchesne post road, Carbon County, Utah, had the following quantities in the July estimate, 1918:

	Cu. yd.
Earth	3,500
Loose rock	1,000
Solid rock	1,800
Total	6,300

The pay roll covering this work, including blasting the ledge rock and large boulders and some leveling and finishing of the grade, amounted to $1,283, giving a unit cost of 20 ct. per cu. yd.

Motor Trucks Loaded by Steam Shovel. When motor trucks are used in earth excavation, the spoil is generally loaded onto a platform or into a hopper, and thence dumped into trucks, in order that the trucks may be kept off the soft ground. In the excavation for the cellar of the Circle Building, at Columbus Circle, New York City, according to *Engineering News*, September 30, 1915, the trucks were sent directly into the cellar being excavated. Three-ton motor trucks were loaded by a steam shovel. which started at one end of the site and worked to the other end, where it turned around and dug its way out. Each truck held 4 cu. yd. of earth. Twenty trucks were employed, each hauling seven loads per day. The trucks were drawn out of the excavation by a cable operated by a hoisting engine.

Motor Trucks for the Public Service Terminal, Newark, N. J. *Engineering and Contracting*, July 12, 1916, gives the following:

The contract by Holbrook, Cabot & Rollins, New York, N. Y., for the Public Service Terminal at Park Place, Newark, N. J., called for the excavation of over 120,000 cu. yd. of earth to be removed from a plot 900 ft. long, with an average width of 140 ft. and a depth of 25 ft. below curb. In addition there were 136 caissons, averaging 8 ft. in diameter, to be sunk to a depth of at least 58 ft. in order to reach rock.

In hauling the excavated material from ten to twelve Pierce-Arrow trucks were employed. The trucks were operated 18 hr. a day, working two 9-hr. shifts of men, one going on at 5 A. M. and the other quitting at midnight. With ten trucks in service the average working per day was 9¾ trucks. The only truck troubles were a few broken springs, due to the rough road over which the hauling was done. With the ten trucks working 18 hr. per day, 28 trips per truck, of 5½ miles, were made. Each truck carried a load of 4 cu. yd. or a total of 112 cu. yd. per day. The trucks were loaded by steam shovel, and the average time of loading was 3 minutes. A concise statement of the operations is contained in the following report, submitted Dec. 2, 1914, after the work was well under way:

Ten 4-yd., 5-ton Pierce-Arrow trucks in 15 weeks carried 53,000 cu. yd. earth excavation 7 miles to make a four-foot fill 18 ft. wide and 2 miles long. This sand, loam and gravel was loaded by a Bucyrus 18-B, 25-ton revolving shovel from the ⅞-yd. dipper directly into the trucks, which took it up a 400-foot 5% grade planked ramp, then over cobblestone and other poor pavement in streets with car tracks and over one drawbridge to the above mentioned fill, which was parallel to, but only connected at intervals with, the turnpike road. The time of loading varied from one to five minutes and up. Unloading, about the same time. The following are the figures:

Number of trucks on the job	10
Number of trucks actually at work, average about..	9½
Number of loads	13,928
Average loads, cu. yd.	3.8
Average weight of load at 98 lb. per cu. ft. tons	4.9
Total mileage for 9½ trucks	98,888
Average mileage 1 truck	10,400
Number of days worked (Sunday not included)	90
Number of days two shifts worked	74
Total shifts worked in 90 days	165
Average miles per 9½ hr. shift for 9½ trucks	600
Average mile per truck per 9½ hr. shift	63

The books show that the overhead expense was $8 a day, which included interest, insurance, garage service, and the salaries of the two drivers. The operating expense was shown to be 18 ct. per mile, which included tires, gasoline, oil, repairs and depreciation. Figuring on the basis of each truck making 154 miles per 18-hr. day, which was the average, the total cost per truck per day was $35.72, and this reduced to the cost of yardage removed, figured out 32 ct. per yd.

In estimating what the cost of doing this work with horse teams would have been, it was figured that there was a saving of approximately 60% in favor of the motor trucks. The net saving on this basis would amount to $550 a day. It is somewhat idle, however, to speculate along these lines, for it is a plain statement of fact that horse teams simply could not have done the work at any cost within the contract time.

Electrically Operated Shovels. *Engineering and Contracting*, Dec. 14, 1910, gives the following: The mechanical equipment of an electrically operated shovel, i. e., the dipper, boom, car and trucks, is built along the familiar lines of the steam shovel. The power equipment consists of a motor of from 50 to 200 hp. to operate the hoist, and two motors of from 25 to 80 hp. to swing the boom and operate the thrust. The hoist and swing motors are located in the car, and are geared to the drums through suitable reducing gears. The thrust motor is mounted directly on the boom, and communicates its motion to the bucket staff through reducing gears connected to a pinion engaging a rack on the staff. The motors are of the crane or mill type, with high torque characteristic, and may be for either direct or alternating current. They are reversing and are under perfect control. When desired the controllers may be connected to the ordinary hand lever used on steam shovels, so that a steam shovel engineer can operate the electric shovel without any trouble. Data in regard to the sizes, capacities and motors required are given in Table I.

TABLE I — ELECTRIC POWER SHOVELS

Weight of shovels Tons	Size of dipper Cu. yd.	Hp. of motors Hoist	Thrust	Swing
30	1	50	30	30
35	1¼	50	30	30
35	1¼	60	30	30
35	1¼	75	35	35
42	1½	75	30	30
65	2	100	35	35
95	3⅛	150	50	50
100	4	200	80	80

The power is ordinarily taken from trolley wires, or from a transformer located near the cut, the feed cables from the power circuit to the car being wound on a retractile reel in the cab and drawn in or paid out as the cut advances. The wiring in the car is enclosed in conduit, and is well protected from moisture and mechanical injury.

The chief objection in the past to electrically operated shovels has been the possibility of damage to the hoist motor when stalled, due to the bucket digging in too deep, or striking a rock or other obstruction in the bank. The heavy current taken at such times

was apt to cause a burn-out, while if the motor was properly protected by fuses or circuit-breakers, their continual opening caused annoying interruptions of service. This difficulty has been overcome by the use of automatic magnet switch control, which protects the motor against such overloads by cutting resistance into the circuit when the current exceeds a certain value.

The motor driving the thrust may be operated either by a drum controller or by automatic magnet control. The motor and its controller must be of such a design that the motor will be able to develop a heavy torque for short intervals of time while standing still, or rotating very slowly. Its duty is to jam the dipper against the bank and hold it there while the hoist operates. As soon as the dipper strikes the bank the thrust motor ceases to revolve, except very slowly, but must still exert full torque in order to keep the dipper against the face of the cut. Its characteristics should, therefore, be such that it may be stalled frequently for a minute or more at a time and still keep developing full-load torque without injury.

The motor driving the swinging boom may be operated by hand control if provided with a magnetic brake to stop the motor quickly and keep the circuit-breaker from opening if the motor is reversed quickly; or may be operated by automatic control without a brake. The operator can place the bucket with greater precision and ease with the automatic control on account of the rapidity with which the magnet accelerates the motor. The controller panels and switches are placed in the rear of the car, while the faster switches or drum type controllers are placed in the front within easy reach of the operator. This makes a very compact and accessible equipment.

Perhaps the most promising field for electric shovels is in connection with electric traction lines, where electric power is usually available at a very low rate. For this service they are mounted on standard gage trucks equipped with air brakes, and may be hauled on the regular tracks, or may be equipped with a trolley and made self propelling, the maximum speed being about 5 miles per hr. Great economy can also be effected by the use of electric shovels in any territory where coal is hard to procure and water power is comparatively cheap, as experience has shown that with current at 2 ct. per kw.-hr. or less, their cost of operation is only about half that of steam shovels. And as part of this saving is obtained by decreased labor costs, and the cost for power is only about one-third the total cost of operating the shovel, local circumstances may determine a saving at considerably higher power rates.

Operating Costs. While the initial cost of electric shovels is more than that of steam shovels, their operating cost is usually less. They can ordinarily be operated by a smaller number of men; the hauling of coal and water is dispensed with; their power economy is greatly superior to that of the steam shovels, and they can be handled with greater precision and rapidity. In addition the electric shovel is comparatively noiseless in operation, which is a great advantage for city use.

Some interesting data in regard to the cost of operation of electric shovels has been obtained by the Vulcan Steam Shovel Co., of Toledo, O. One of these shovels has been operated by the Milwaukee Electric R. & Light Co. for several years, at a consumption of approximately 100 kw.-hr. per 10-hr. day. It is used for loading gravel at a gravel bank and is operated by two men, who load from 300 to 400 cu. yd. of gravel per day. The average daily expenses of operating this shovel are:

One engineman	$2.00
One craneman	1.75
Electric power at 1.5 ct. kw.-hr.	1.50
Oil, waste, repairs, etc.	0.75
Total per day	$6.00

The Chautauqua Traction Co., of Jamestown, New York, has been operating a shovel equipped with a 75-hp. hoist motor, since 1907. This shovel is used in loading a mixture of gravel, sticky clay and sand, which is very hard to dig, and is operated by 2 men on the shovel and 2 pitmen. The current consumption on a special test averaged 163 kw.-hr. per 8-hr. day, and 534 cu. yd. of material were loaded in an average day. The total expenses per day, including the pitmen, were $8.80, or approximately 1.7 ct. per cu. yd. The maximum capacity of this shovel is about 1,000 cu. yd. per 8 hr. If operated at this capacity, the power consumption would be increased in proportion to the output, but the labor charges would be the same as figured in the above statement. This would bring the cost of shoveling down to about 1 ct. per cu. yd.

Comparison of Cost of Steam and Electrically Operated Shovels. Where the cost of electric energy is very low, or where the smoke and sparks of a steam plant constitute a nuisance, as in a city, the substitution of electric motors for the steam power plant on shovels is profitable. Electric shovels may be divided into three classes: (1) the friction-electric, which is operated by a single constant-speed motor with friction clutches; (2) the three or four motor direct-current equipment; (3) the three or four motor alternating-current equipment. The friction-electric shovel, according to Mr. H. W. Rogers in *Engineering News*, Mar. 19,

1914, does not compare favorably with the other two classes as far as speed is concerned, although it may be operated as cheaply.

The saving in operating cost of the electric shovel over the steam shovel depends on the comparative cost of coal and electric power, and will vary for different localities. However it should be remembered that an electrically operated shovel eliminates the fireman, watchman, coal passer, teaming for ½ day, the use of water, and considerable waste. Assuming that the shovel working year consists of 150 days, and that the shovel is working but one shift a day, the following is the approximate comparative cost of operation of steam and electric shovels.

Labor per shift	Steam	Electric
Shovel runner	$ 6.00	$ 6.00
Craneman	4.00	4.00
Fireman	2.50	
Six pitmen at $1.75	10.50	10.50
One watchman	1.75	
One coal passer	1.50	
Teaming (½ day)	2.50	
Oil and waste	1.50	0.75
Total labor	$30.25	$21.25

	Steam	Electric Direct current	Electric Alternating current
Interest at 6%	$ 5.20	$ 7.75	$10.85
Depreciation at 4⅔%	4.03	6.00	8.43
Repairs at 10%	8.66		
Repairs at 6%		7.75	10.85
Labor per shift	30.25	21.25	21.25
Total exclusive of power	$48.14	$42.75	$51.38

The above is based on the following first costs of shovels: Steam shovel, $13,000; direct-current electric shovel $19,400; alternating-current electric shovel $27,000.

Revolving Electric Shovel on Street Railway Work. The following is from *Electric Railway Jl.*, Dec. 2, 1911: For excavating trenches for new and rebuilt tracks, the United Railway Co., of St. Louis, Mo., used a Thew No. 0 (18-ton) electric shovel with a ⅝-yd. dipper. In the suburbs in ungraded streets, where the digging is to depths of 3 or 4 ft., the truck on which the shovel is mounted is self-propelled on 4-ft. sections of temporary track, moved from the rear to the front of the shovel as the work proceeds.

Where a shallow trench is being excavated, the shovel must be moved forward frequently, and therefore a special cradle for carrying the shovel truck over the trench on temporary track, laid in advance, was devised. This cradle and truck is illustrated in Fig. 69. The cradle was built of 10-in. channels and equipped

with four 12-in. double-flanged wheels. It is bolted to the track. When supported by this device the propelling mechanism of the shovel was useless. Therefore a push car, fitted with axles having wheels set at both standard and 10-ft. gage, was used to move the shovel. A trench 21 in. deep and 7.5 ft. wide, was excavated at the rate of 300 lin. ft. or 146 cu. yd. in 10 hr., under city conditions.

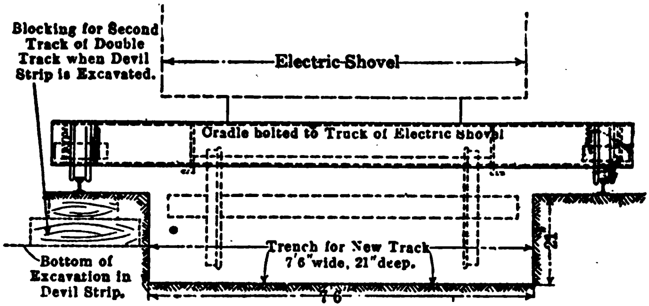


Fig. 69. Special Truck for Automatic Shovel

Power Consumption of Electric Shovels. For excavating gravel for the construction of a dam across the Carson River at Lahontan, Nev., a Bucyrus, 2½-yd. dipper, electric shovel was employed. This machine, its performance and power consumption were described by Mr. C. E. Hogle in *Engineering News*, Jan. 23, 1913.

The hoisting machinery was geared to a 115-hp., 440-volt, 3-phase, 60-cycle, variable speed induction motor which also propelled the shovel. The swinging gear and the thrust mechanism were each driven by a 50-hp. motor. In addition, there was a 2-hp. motor that furnished power to an air compressor which supplied air for brakes. On the rear of the shovel were three 90-k.v.a., single-phase transformers which stepped down the line voltage from 2,300 to 440. Current was supplied to the shovel through 700 ft. of triple conductor cable, armored with D-shape steel tape. This was laid on and dragged along the ground.

In order to get some definite data regarding the performance and power consumption of this shovel, a test was made at Lahontan, Nev., on the morning of Oct. 14, 1912. A polyphase recording watthour meter, a polyphase curve-tracing wattmeter, a curve-tracing ammeter and a voltmeter were installed in the 2,300-volt circuit supplying the shovel. The speed of the paper

in the curve-tracing ammeter was 10¾ in. per min., while the speed of the paper in the curve-tracing wattmeter was 11 in. per min. The different operations of the shovel were noted by a separate observer, who signaled to the instrument observers and also timed the different operations with a stop-watch.

The shovel was working in a gravel bank 10 to 12 ft. deep, and the clear lift of the dipper was 16 ft. The conditions of the work were not favorable to making a test for determining the maximum excavating capacity of the shovel. Only two six-car trains could be spared for the test, and no attempt was made to adjust the train length to the material to be excavated. The shovel has, however, been operated at very nearly four cycles per minute, a cycle being a dipper load.

The tests lasted throughout six trains of six cars each and current and wattmeter curves were taken throughout the whole time covered by these six trains, thus giving a complete record of every operation. Only the curves for train No. 12 are shown in the accompanying figures. During the test of train No. 12 the voltage varied between 2360 and 1960.

The data derived from these tests are grouped in the accompanying table.

ELECTRIC SHOVEL TEST U. S. RECLAMATION SERVICE; TRUCKEE-CARSON PROJECT

Lahontan, Nevada, Oct. 14, 1912

No. train	No. cycles	Cubic yards	Time in minutes required to load trains	Cycles per minute	Maximum peak per train Amperes at 2,300 v.	Maximum peak per train kilo. watts	Highest average kws. per cycle	Power consumed loading trains kw.hr.
9	12	24	4.08	2.94	88	226	112	6.22
10	12	24	4.57	2.62	97	259	132	7.68
11	12	24	4.75	2.52	87	236	120	6.75
12	12	24	4.00	3.00	90	225	118	6.40
13	11	22	4.00	2.75	99	252	102	7.12
14	12	24	4.50	2.67	90	238	126	6.15
Totals and averages	71	142	25.90	2.75	..	...	...	6.72

Total time elapsed from start of train No. 9 to end of train No. 14 45.5 min.
Total time of loading trains .... 25.9 min.
Total time of delays, moving up, waiting for cars, etc. .... 19.6 min.
Digging and loading period is 57% of total time.
Delays, moving up, etc., is 43% of total time.
On the above basis the amount of gravel excavated per 8-hr. day is 1,500 cu. yd. of loose gravel.
Total power consumed by six trains is 42.96 kw.-hr. or, 7.16 kw.-hr. per train.
Total number of trains per 8-hr. day = 63.3.
Power consumed by shovel per 8-hr. day = 453 kw.-hr.
Power consumed per cu. yd. of loose gravel = 0.302 kw.-hr.

Cost with Electric Shovel. The Chautauqua Traction Co., Jamestown, N. Y., used a Vulcan electric shovel during 1908 for

excavating ballast. This machine was described in *Engineering and Contracting*, Jan. 6, 1909. Complete, it weighed about 40 tons. Power was furnished through three variable speed, D. C., 600 volt, 700 rpm. motors. The hoisting motor was 75hp., and was provided with an automatic magnetic controller and circuit breaker for throwing off the current when extraordinarily hard material was encountered, thus preventing any danger of the motor stalling and burning out. The swinging gear motor was 30-hp., and the crowding engine motor was 30-hp., also.

Mr. A. N. Broodhead, president of the road, is authority for the following cost data.

1 man	$0.33
1 man	0.25
2 men, at 15 ct.	0.30
20,346 K. W. hr. at .0088 ct.	0.18
Oil and waste (estimated)	0.04
Total cost, per hr.	**$1.10**

The amount excavated each hour was 66⅞ cu. yd., giving the following costs per day:

8 hr., at $1.10, $8.80.

8 hr. at 66⅞ cu. yd., 534 cu. yd.

$8.80 divided by 534 cu. yd., 1.64 ct. per cu. yd. for loading.

The material excavated was a mixture of gravel, sticky clay and sand, which made it hard to dig, but as will be seen from the above figures, the cost of this work was very low. There are, of course, several causes for this, the principal ones being, first, that as the shovel requires no boiler, the cost of a fireman and of hauling coal and water are eliminated; second, that the work of the shovel was so intermittent and when the shovel was idle no power was being consumed as would be the case with steam shovel. The shovel could have been operated to its maximum capacity, which would have given twice the yardage, at nearly the same cost as the men had to be paid whether they were working or idle, and the additional cost for power would not have been more than twice what it was which, on the same basis, would mean 1,068 yards at a cost of $10.24, or less than 1 ct. per cu. yd.

Revolving Electric Shovel in a Gravel Pit. In *Engineering and Contracting*, July 22, 1908, were published data relating to the cost of operating a Thew No. 1 electric shovel, owned by the Brautford & Hamilton Electric Railway, Canada. The machine weighed 25 tons, was furnished with a 1 cu. yd. dipper, and was equipped with a 35-hp. motor. Two men composed the operating crew.

The conditions under which this shovel was worked were most favorable. It worked in a gravel pit, the depth of the cutting

being about 14 ft. The material was very easy to handle. The pit was very long, so the shovel did not need to be shifted often, and inasmuch as it makes a complete swing, the time of shifting was very short. A special trolley wire was used for the motor in the shovel, so that the current was constant. No time was lost in moving the shovel ahead, as two men working in the pit would clean out a space directly in front of the shovel, when the machine would pick up a section of track in the rear and place it in the newly cleaned space. While the two pitmen were fixing this piece of track the shovel would take gravel from the side, so that not more than a minute was required to move the shovel ahead.

The company had an ample supply of flat cars on each of which were loaded 14 cu. yd. loose measurement. There were also plenty of motors to haul the trains away, six cars making up a train. One motor car was used to spot the cars continuously, and a man was employed as a signalman to assist in spotting cars. The shovel worked a 10-hr. shift, and any repairing and overhauling was done at night by another crew. Operating in this manner, as a rule, the shovel was loading the maximum time, there being but little time lost in placing cars under the dipper and in moving ahead. With the electric current no time was lost in taking supplies of water and fuel.

The trains that carried the gravel away were operated by a motorman and one other man. A plow, pulled by the motor car, was used to unload the cars, and two men were kept on the dump to handle the cable of the plow and to attend to other details.

Owing to the large supply of cars and motors, to the favorable conditions in the pit and the method of operating, the output of the shovel per day did not vary much. A great many days 100 flat cars were loaded each day and hauled away. This meant an output of 1,400 cu. yd., loose measurement, or 1,050 cu. yd. place measurement.

The labor cost of operating per day was as follows:

Superintendent	$ 4.00
Shovel Crew:	
2 shovelmen	6.00
2 pitmen	3.00
Spotting Cars:	
1 motorman	3.00
1 signalman	1.50
Transporting (2 trains):	
2 motormen	6.00
2 trainmen	3.00
Dump:	
2 men	3.00
Total per day	$29.50

With 1,050 cu. yd. moved per day we have the following unit cost for labor:

Superintendence	$0.004
Loading	0.013
Transporting	0.009
Dumping	0.003
Total per cu. yd.	$0.029

To this must be added charge for power, plant charges, repairs and track work. When the haul increased in length additional trains were added, so that the shovel was still kept busy loading the cars.

On some days the output fell to 80 car-loads or less. With this output, namely 800 cu. yd. place measurement per day, the unit labor cost was:

Superintendence	$0.005
Loading	0.017
Transporting	0.011
Dumping	0.004
Total per cu. yd.	$0.037

The above show low records of cost for steam shovel work, but they make evident the economical features of excavating with a shovel of this type, as small and inexpensive crews are employed, and a comparatively large output can be obtained by using the best methods of operating.

Electric Shovel on an Electric Railway. The shovel used was a 14-B Bucyrus electric operating at 575 volts. A 30-hp. hoist motor and two 15-hp. swing and thrust motor equipment used on this shovel with a ⅝-cu. yd. dipper. The shovel weighs 19 tons. The work recorded was on the electric lines of the Wilkes-Barre Ry. Co., and the data given here are taken from the *Excavating Engineer* for January, 1915, and rearranged by *Engineering and Contracting*, Feb. 17, 1915.

Handling a 3,500-cu. yd. Slide. In May, the shovel tackled a 3,500-cu. yd. slide on the short line on Harvey's Lake Division. Work was started April 19 and was completed on May 8. The material removed was hardpan, loosened by the action of the frost. It contained a considerable amount of gravel and small boulders. The latter running in size up to 2 and 3 cu. ft. When dry this material answered perfectly the definition of hardpan. In the winter months, the frost penetrated this slope, which varied from 20 to 60 ft. in height above the track for a distance of about 1,000 ft. In the spring when the frost came out, a layer of this material, averaging perhaps 1½ ft. in thickness, slid down the slope, covering one of the tracks to a depth of from

2 to 10 ft.; the outside track was kept open by hand with some difficulty. When this material was dried out somewhat, the shovel was started at the end of the slide, operating from the covered track and loading into cars on the outside track.

Two motor cars and two 10-yd. all-steel Western side air-dump cars were used. One motor car was used for spotting one car, while the other motor car was hauling the other car to and from the dump. The distance to the nearest switch was about 800 ft. and the shovel was idle while the spotting car was taking the loaded car to the switch and returning with an empty. On this account considerable time was lost. The record of a typical day's run shows that the shovel was in actual operation 225 min. out of a 10-hr. day. The material was hauled an average distance of about a mile and dumped along the fills for the purpose of strengthening the embankments, and preparing for a double track. When the cars were dumped the bulk of the material was precipitated down the side of the embankment. A thin layer of ashes spread on the steel bottom of the cars before loading greatly facilitated this free dumping.

Although probably not more than 20% of the material excavated was actually spread by hand on the dump, yet it will be noted that this part of the operation represents nearly 50% of the labor cost. Approximately 3,500 cu. yd. of material was removed in 11 working days. The work was considerably hindered by several trees that came down with the slide, which had to be cut up and removed. This material is particularly difficult and expensive to remove by hand, and when wet, it is almost impossible to handle by reason of it adhering to the shovels. The cost of removing a smaller slide that occurred at this location, the previous season, was approximately 50 ct. per cu. yd.

The total cost of the shovel operation in this instance, as shown in the table below, including spreading on the dumps, spotting cars, hauling, etc., was 12.15 ct., or less than one-quarter of hand labor cost. One of the principal advantages of the shovel was that the material could be handled when in a semi-fluid state, thereby making it possible to get the track in operation. As an indication of the output obtained under these conditions, on May 4, 23 (10-yd.) cars or approximately 345 cu. yd., were loaded in 227 min., the shovel moving ahead in this time 36 ft. On May 7, 22 (10-yd.) cars were loaded in 225 min., moving ahead 40 ft. on a curve. The material weighed 125 lb. per cu. ft.

The cost of handling this slide as given by Mr. Hoffman, steam shovel engineer, was:

Labor:	Ct. per cu. yd.
Excavating and loading	2.1
Spotting cars	1.3
Hauling and dumping	1.8
Spreading on dump	4.0
Total labor	9.2
Including supervision, about	10.0

Power:	
Estimate of power used by shovel is 160 kw.-hr. per day @ 1½ ct., equals $2.40 per day, or	0.75
Power used by motor car hauling to and from dump — 175 kw.-hr. per day, or	0.80
Total for power	1.55

Repairs, supplies, etc., were negligible on this job, but assumed to average $2 per or 60 ct. per cu. yd.

Summary:	Ct. per cu. yd.
Labor, including supervision	10.00
Power, excavating and hauling (1 mile)	1.55
Repairs, supplies, etc.	0.60
Total	12.15

Note.— No allowance for interest and depreciation on equipment.

Cost of Grading Side Cut. This was a sidehill cut about 800 ft. long with a depth on the center line ranging from 1 to 6 ft., averaging about 3½ ft. The cut on the high side ranging from 3 to 10 ft., averaging about 6 ft. The cut contained 2,450 cu. yd. The preliminary work consisted of grading a temporary roadbed parallel with and about 14 ft. distant from the center line of the permanent track. Upon this temporary roadbed the ties and rails were laid and used for hauling the material to the dump, after which the track was thrown to its permanent location.

A motor car and a Western 10-yd. steel side dump car were used for hauling the material. The grade was very steep and the track in poor line and surface, necessitating slow running to and from dump. The power on this line was weak and very unsatisfactory. It is probable that the output would have been increased at least one-third, if satisfactory power had been available. Generally the material was loam and good digging. Shale rock was encountered, however, in the bottom of the cut and about 25% of the material excavated was shale ranging from soft, easy digging to very hard. The time required to make the cut was 12 working days during which time the shovel work was delayed 44 hr. principally by lack of power. The material was dumped on a fill about 600 ft. in length, ranging in depth from 2 to 8 ft., averaging about 5 ft. About 200 lin. ft. of crib

trestle was erected over the deeper portion of the fill. On the remainder of the fill the track was laid on the original surface and gradually jacked up to grade. The cost figures follow:

Labor:	Total	Per cu. yd.
Grading for temporary track	$ 50.00	$0.0204
Moving shovel into position	13.24	.0054
Excavating and loading material	107.74	.0438
Hauling and dumping material	60.74	.0247
Building crib trestle	25.00	.0102
Spreading material on dump and raising track	134.20	.0547
Watchman (⅔ of watchman's time charged to this job)	12.80	.0052
Blacksmith	5.90	.0024
Throwing track to permanent position	30.00	.0122
Total	$439.62	$0.1790
Supervision	43.96	.0179
Total	$483.58	$0.1969
Power:		
To operate shovel, 1,260 kw.-hrs. @ 1½ ct.	$ 18.90	$0.0088
Hauling material, 480 kw.-hrs. @ 1½ ct.	7.20	.0029
Total	$ 26.10	$0.0117

Summary:

Labor, including supervision	$0.1969
Power (shovel and train)	.0117
Total per cu. yd.	$0.2086

Note.— No allowance for interest and depreciation on equipment.

Revolving Electric Shovel on Street Ry. According to *Engineering and Contracting*, July 19, 1916, in building its 79th St. line, the Cleveland Railway Co. had to do a considerable amount of excavation for which it employed an electrically driven Thew automatic shovel.

This shovel is of the horizontal crowding motion type and has several other features of interest. It weighs 13 tons, and has a dipper with a capacity of ⅝ cu. yd. and a clearance height over the house of 12 ft. 2 in. It is mounted on regular car wheels on which it travels on the car tracks and in addition is equipped with a set of auxiliary traction wheels, 33 in. in diameter, and 15-in. tread, which permits it to run under its own power over the ground, pavement, or wherever it is desired to take it.

The entire motive power for traction, hoisting and swinging consists of one 20-hp. Westinghouse compound-wound 550-volt direct-current motor with a starting and reversing control equipment. The motor operates at approximately constant speed, the various motions being controlled through suitable friction and gears. The current is usually admitted to the shovel through

a flexible insulated cable connected to a switch on the truck frame and transmitted through copper rings to brushes suspended from the swinging turntable.

The use of one motor appears to be a particularly desirable feature for reducing the initial cost and affording greater flexibility of action in the frequent reversals of the various operating motions; it also means the operation of three levers instead of three separate controllers, and a gain in time over starting and stopping three separate motors. It is distinctly a one-man machine.

The boom is of the jackknife type with an adjustable section that can easily be located, allowing the shovel to pass under the trolley wire, without interfering in any way with the efficiency of its operation. The shovel swings through a complete circle, delivering the excavated material at any desired point.

A buffer is furnished which takes up the shock that occurs when the shovel strikes a hard piece of excavation. This allows the shovel to be released and relieves the whole machine from the strain to which it would otherwise be subjected.

Th cab is cut away so as to allow plenty of room for passing cars, a feature of particular importance when used on street railway work.

The cost was:

Loading:	
Shovel man @ 40 ct.	$ 4.00
Four laborers @ 21 ct.	8.40
Current, oil, repairs, etc.	1.50
Loading per day	$13.90
Hauling:	
Four men @ 26 ct.	$10.40
Four men @ 19 ct.	7.60
Two men @ 30 ct.	6.00
Hauling per day	$24.00
Dumping:	
One foreman @ 30 ct.	$ 3.00
Six laborers @ 20 ct.	12.00
Dumping per day	$15.00
Loading, Hauling and Dumping:	
Cubic yards loaded in 10 hr. May 8	540
Loading per cu. yd.	2.6 ct.
Hauling per cu. yd.	4.4 ct.
Dumping per cu. yd.	2.8 ct.
Loading, hauling and dumping per cu. yd.	9.8 ct.
Lineal feet excavated on this work	2,700
Number of 10-hr. shifts operated	12

Lineal feet excavated per 10-hr. shift	225
Cubic yards loaded (place measure, per 10-hr. shift)	450
Average loading cost, 450 yd. @ $13.90	3 ct. per cu. yd.
Average hauling cost, 450 yd. @ $24	5½ ct. per cu. yd.
Average dumping cost, 450 yd. @ $25	3⅓ ct. per cu. yd.
Average loading, hauling and dumping cost	11⅔ ct.
Length of haul, approximately	6 miles
Average hp. used in moving shovel	15.0
Maximum hp. used in moving shovel	20.2
Average hp. used in operating shovel	11.7
Maximum hp. used in operating shovel	43.6

A Shovel on the Boom of a Derrick. *Engineering and Contracting*, Nov. 22, 1911, gives the following: Fig. 70 shows an ordinary revolving mast derrick with a new attachment known as the Bishop's Derrick Excavator.

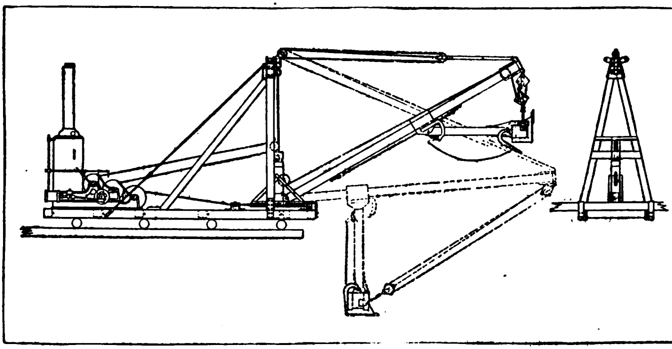


Fig. 70. Excavator Mounted on "A" Frame Traveler.

The carriage at the base of the dipper arm is made of steel plates and contains four rollers which allow it to run up and down the boom. Between the two side plates and below the rollers is a cross channel, from which is suspended by bolts two plates, one above and one below the stationary wire cable which is attached to the boom at the heel and peak. On these plates are cast iron grips to hold the carriage to the wire when desired. The end of the dipper arm is provided with a cast iron eccentric or cam shaped shoe and when the dipper arm is raised towards the boom as shown in its dumping position, the pressure is released, and permits the carriage to roll on the boom, but when the dipper arm is released, as shown in the digging position, the large end of the cam or eccentric presses the lower grip plate against the wire and holds the carriage until the dipper arm has been raised sufficiently, when the small end of the cam or eccentric releases the grip, and the carriage follows up the boom.

The automatic dumping arrangement is shown in the illustration. This is a lever arm rigidly attached to the carriage, which acts on the lever shown attached to the dipper arm. When the dipper arm is brought almost parallel with the boom these levers come in contact and the door latch on the dipper is caused to be pulled back, thus releasing the bottom of the dipper. One man is required to operate the shovel with a two-drum engine and swinging gear. One drum is required to raise and lower the boom and the other to operate the shovel. The operator slacks on the digging line until the carriage rolls down the boom, bringing the shovel to the desired position. He then releases entirely

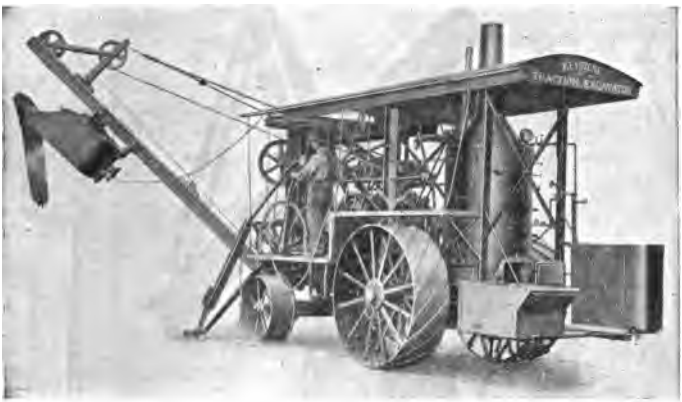


Fig. 71. Keystone Excavator Equipped with Skimmer. Boom Raised and Bottom of Skimmer Dropped as When Dumping.

and the shovel swings back under the boom, the cam operates the grip holding the dipper arm rigidly from sliding in the boom and at the same time the boom is lowered and its weight is brought onto the dipper. The weight of the boom is allowed to rest on the shovel which it is digging.

The excavator is made by the Union Iron Works, Hoboken, N. J.

The Keystone Traction Excavator. *Engineering and Contracting*, May 27, 1914, gives the following: For the Keystone excavator three different types of scoops are provided, namely, a dipper, Fig. 72; a skimmer, Fig. 71, and a ditcher scoop, Fig. 73. All three scoops are about equal in capacity, holding approximately two-fifths of a yard, and can be operated at about the same speed, two to three times a minute in free digging.

The "skimmer scoop" has a flat bottom. It is used largely in street grading and for comparatively shallow excavation. It is carried on rollers which slide along the 16-ft. boom. When the skimmer type of shovel is to be used the dipper sticks are removed and the tackling changed. The form of the scoop makes it possible to have a smooth, level, finished surface in grading. Since the skimmer scoop can be moved 11 ft. along the boom, its operation in digging is like that of a drag scraper.

The ditching scoop differs from the dipper and skimmer in

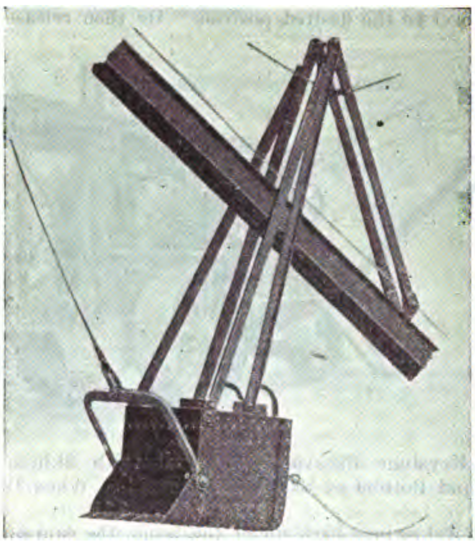


Fig. 72. Dipper Bucket for Keystone Excavator.

shape and is employed in making ditches for sewers, water mains, etc. It is good for a width of 15 in. to 44 in., and a depth of 6 or 8 ft. The best record with this type of scoop was made by S. B. Markley, contractor of Woodlawn, Pa., on work at Conway, Pa. He dug in eight hours 400 ft. of ditch 4½ to 5 ft. deep and 36 in. wide at the bottom. In ditching work the action of the dipper scoop is reversed, the scoop being carried on a hinged arm at the extremity of the boom, and the machine being moved backward as the ditch is completed.

The dipper scoop is similar to the ordinary steam shovel. The best record hitherto achieved with the dipper scoop was 142 loads,

dump wagons of 1½-yd. capacity being well filled, in 6½ hours' running time. For short periods wagons were loaded at the rate of one in each one and a quarter minutes.

Two men are required to manipulate the machine. The boiler is 36 x 69 in. and is of the inverted porcupine style. The engine is 8 x 8 in. The weight of the complete machine is about 16,000 lb. Its traveling speeds are 1 and 3 miles per hr. The machine is made by the Keystone Driller Co., Beaver Falls, Pa.

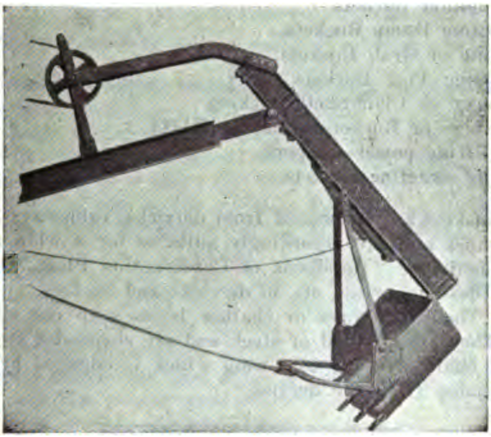


Fig. 73. Ditcher Bucket Equipment for Keystone Excavator.

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CHAPTER XII

METHODS AND COST WITH GRAB BUCKETS AND DUMP BUCKETS

For the purpose of a study of methods and cost of handling earth in buckets the following classification will be adhered to:

Hoist Buckets (Chapter XII).
- a. Non-Digging Dump Buckets.
  1. Skips.
  2. Trunnion Buckets.
  3. Bottom Dump Buckets.
- b. Digging or Grab Buckets.
  1. Orange Peel Buckets.
  2. Power or Clam-Shell Buckets.

Drag Scrapers or Buckets (Chapter XIII).
- a. Non-lifting power scrapers.
- b. Lifting dragline buckets.

Hoist buckets are suspended from derricks, cableways, or locomotive cranes and are accordingly suitable for a wide range of uses. Consult the "Handbook of Construction Plant," by R. T. Dana, for designs, prices, etc. of derricks and buckets.

Skips. These are trays or shallow boxes with one side open, Fig. 1. They are of wood or steel, and are suspended from three points by chains leading to a ring which is engaged by a hook and suspended from the derrick.

Fig. 1. Wooden Skip.

Cost with Skips. In foundation work it is frequently necessary to use a derrick for handling the earth. Either wooden "skips" or iron buckets are filled with earth by shovelers, and a man-operated, horse-operated, or power-operated derrick is used to lift the buckets out of the way.

Work of this character is always expensive for only a few shovelers can be worked in the pit, and as a consequence the derrick is never worked to its capacity. The following was the cost on one job: A stiff-leg derrick with 35-ft. boom, and three wooden skips (1 x 4 x 4 ft.) constituted the plant. A team with driver was used to raise the skips. The output in soft digging per 10-hr. day was 100 cu. yd.

6 men loading skips at $1.50	$ 9.00
1 man in pit hooking on skips	1.50
2 tagmen swinging and dumping	3.00
1 team with driver	3.50
1 foreman	3.00
100 cu. yd. at 20 ct.	$20.00

This was an excellent record, but the digging was fairly easy. Four skips made a 1.5-cu. yd. wagon load, and it took 1.5 min. to load, hoist, swing and dump a skip, half of which time was occupied in swinging the derrick boom out and back.

The setting up of a small derrick of this kind will take a crew of men 3 hr. or less if the foreman knows what to do, but we have known green foremen to be all day getting the derrick up. Where there are trees to anchor to, a guy-derrick is to be preferred, for there are not several tons of stone to be handled as on a stiff-leg derrick which must be weighted down. Moreover a guy-derrick is quite easily shifted a long distance even while standing. Some contractors set the foot of the mast of a guy-derrick on a framework that rides of skids, and it is then easily dragged over the ground even while upright. A hand winch is never to be used if it can be avoided, for it is too slow a method for moving earth. Wagon boxes of special design are sometimes made to be lifted off the wagon bed with their load of earth and dumped into scows. Wooden skips with two sides only might be loaded by drag scrapers, then lifted by a derrick and dumped directly into wagons or into a bin from which the earth could be drawn off into wagons.

Foundation Excavation with Derrick and Car Bodies. The construction of an addition to the power plant of the Indiana Michigan Electric Co., South Bend, Ind., was described in *Engineering and Contracting*, Feb. 28, 1912.

The excavation for each foundation was 36 ft. square, and was carried down 30 ft. The pit was tight sheeted with 2 x 12-in. plank, double lapped. The material encountered in the excavation consisted of sand and gravel, to a depth of about 20 ft., and then of clay to 5 ft. in depth. From this point down there was blue clay, with an occasional pocket of quicksand. The

sheeting was driven by hand, as the excavation progressed, by two men who were employed at this work continuously.

The material was excavated by hand and shoveled into the body of a ¾-cu. yd. car. This body was V-shaped, and was fitted with legs so that it could stand upright on the ground, or could be used on the car. A 3-way chain was rigged so that the car body could be swung from the derrick. In the pit were employed from 4 to 6 men to each bucket, and each man averaged about 3 cu. yd. of earth per day. There were 4 or 5 buckets used in the pit.

Trunion Buckets Loading Wagons Through a Hopper or Table. J. C. Black, in *Engineering and Contracting*, Dec. 11, 1907, gives the following: The work was the digging of a basement in Portland, Oregon.

The property was a corner lot 100 ft. square and nearly level, and had been occupied by some frame buildings at least one of which had a cellar and stone foundation. About 8,000 cu. yd. of material were handled, the average total depth being about

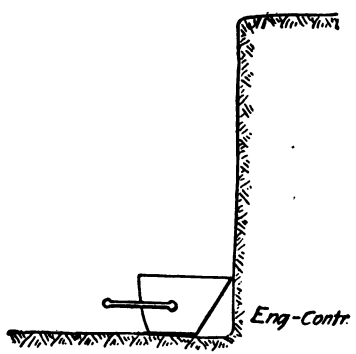

Fig. 2. Method of Filling Buckets.

20 ft. Almost the entire excavation was a mixture of yellow clay and sand with a small amount of loam. Excavation was begun at the inner corner of the area and was rapidly carried to full depth at that place, thus affording a steep bank against which to work. A crane lifted the material from the pit in buckets, and dumped it on a table or tipple from which it was loaded into wagons.

A bucket to be filled was placed against the face of the bank,

as shown in the sketch, Fig. 2, and was loaded partly by shovels, partly by material picked from the face so as to fall into the bucket and partly by slabs or spalls of earth pried from the top of the bank with a crowbar. This last method was exceedingly effective, for the earth broke off easily, and one man with a bar at the top of the bank could loosen large pieces with comparatively little effort. Sometimes enough earth to fill a bucket would fall at once, while that which fell outside the buckets was in a condition to be easily handled by shovels. It is probable that this method of prying from the top of bank would prove uneconomical for some classes of material, but in this material it worked well.

The crane consisted of a 35-hp. hoisting engine and a wooden derrick frame mounted on a timber sledge. The maximum reach of boom from center of rotation was 30 ft., but, by lowering a bucket almost to the ground and then having it set swinging by the men in the pit, it was possible to drop it some 20 ft. beyond the end of the boom, thus affording a maximum working range of 80 ft. from point of loading to dump.

When necessary to remove the crane to a new position on the work, a cable was made fast to something which would serve as an anchor and it was made to move itself. Rollers were generally used under the sledge. An hour to an hour and a half was the time consumed in moving. Axles on which could be placed a pair of rear wagon wheels were fitted to the sledge near one end, and at the other was a place for the forward truck of a wagon, thus making transportation from one piece of work to another a very easy matter.

The 5 buckets were made in Portland. The nominal capacity was 35 cu. ft. each. They were dumped by tilting; the catch which held them upright being released by the man at dumping table. This table (Figs. 3 and 4) or tipple was the most interesting feature of the plant. It consisted essentially of a steel frame supporting two trays under which the wagons to be loaded were driven. The trays are each about 1 ft. deep, 4 ft. wide and 6 ft. long, and when closed, met at the center forming one large tray. In dumping, each tray rotated about an axis of its own near its center, the weight of the earth causing it to dump automatically when released, and the position of its own center of gravity making it automatically return to a horizontal position after having emptied its contents. Its effect was to "trim" the load so that little or no work was required to spread it on the wagons, while the amount spilled was negligible.

It will be seen at once that the table affords a storing place for materials, and thus reduces the lost time due to irregularity

in arrival of wagons. Usually only one bucket of earth was placed upon the table at a time.

A record of wagons was kept by the dumpman with pegs on a tally board mounted on the table.

Of course this loader was not so near perfection but that it was occasionally necessary to clean up around it, especially as it was

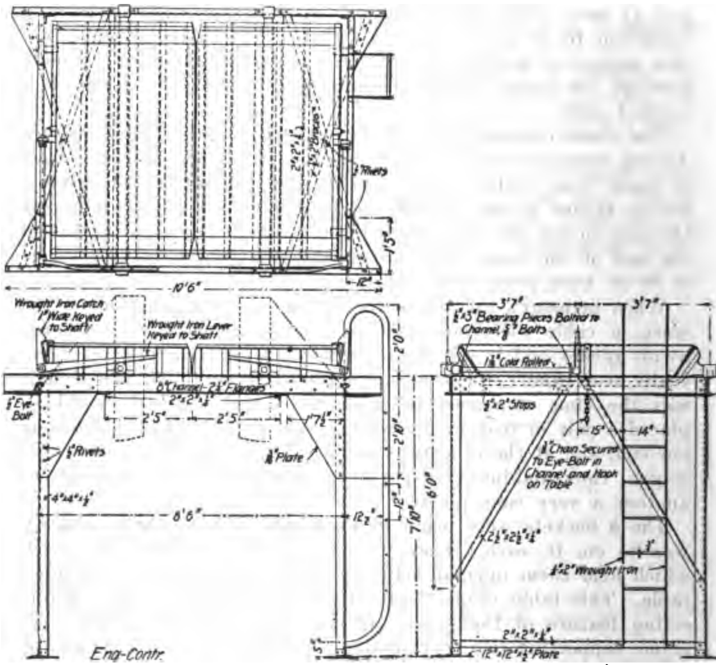

Fig. 3. Plan, Front Elevation and Side Elevation of Dumping Table.

a busy street. However, it reduced work of that nature to a minimum. When necessary to shift the position of the table, a timber yoke was fastened to the frame by chains, and the whole thing was moved by the derrick.

Light for the night crew was supplied by three clusters of six 32-c.p. incandescents each, backed by reflectors.

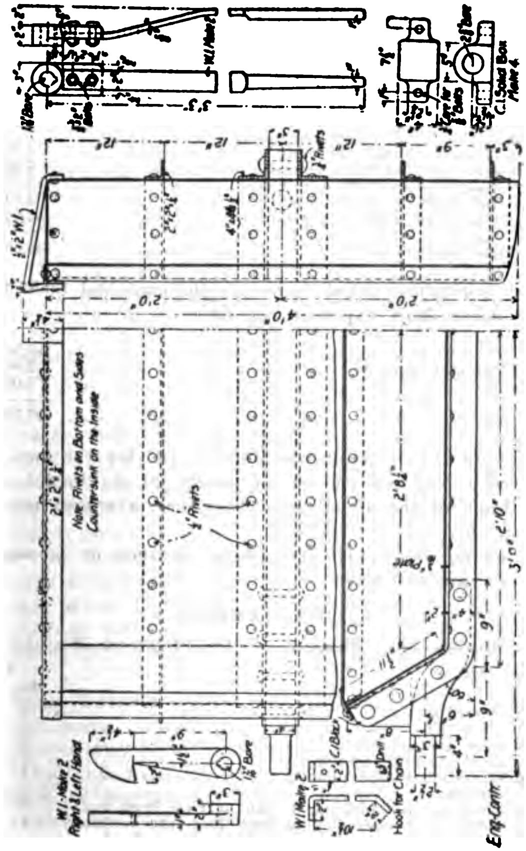

Fig. 4. Details of Design of Dumping Table.

Studebaker dump wagons were used, and, by an extension to the top, they were made to hold 2½ cu. yd. each when level full; which shows that two buckets of material were required per load.

The cost of the plant was approximately as follows:

Locomotive crane (including cable)	$4,500
Five buckets at $145	725
Loading table	500
Total (exclusive of small tools)	$5,725

Two crews of equal size were employed most of the time, a total daily force being about as shown in the table. The rates of wages are assumed, and would, of course, vary from time to time, and with location.

Two foremen, at $4 per day	$ 8.00
Two engineers, at $4 per day	8.00
Two firemen, at $2.50 per day	5.00
Two signalmen, at $2.50 per day	5.00
Two hook tenders, at $1.75 per day	3.50
Two dumpmen, at $1.75 per day	3.50
Thirty laborers, at $1.75 per day	52.00
Total daily wages	$85.50

One man sometimes acted as both signalman and hook tender. Assuming other daily expenses, we have:

Labor	$85.50
Fuel, oil and supplies	5.00
Repairs	5.00
Total	$97.50

The average daily output was 500 cu. yd. for the two crews, which gives a cost per cu. yd. of nearly 20 ct., loaded on the wagons. Each of the 30 laborers, therefore, averaged nearly 17 cu. yd. per day.

The following details are from data obtained by personal observation at various times:

LOADING BUCKETS

(All Buckets Filled Heaping — 35 Cu. Ft. Struck Measure)

Bucket No.	Labor	Time Min.	Time Sec.
1	3 men shoveling	3	50
2	4 men shoveling	4	45
3	3 men shoveling	5	10
4	3 men shoveling and picking	5	30
5	2 men shoveling, 1 man picking	4	55
6	3 men shoveling	3	45
7	2 men shoveling and picking, 1 man barring from top	3	15
8	2 men shoveling, 1 man picking from face into bucket	4	00
9	1 man shoveling, 2 men picking from face into bucket		
10	2 men shoveling, 1 man picking and barring	3	45
11	1 man shoveling, 1 man picking into bucket, 1 man barring	3	50
12	2 men shoveling, 1 man barring down from top	5	00
	Total, 28 men shoveling, 10 men picking and barring	50	53
	Average 2⅓ men shoveling, 5-6 men picking and barring	4	15

This is equivalent to a bucket of earth loosened and loaded by one man in 13½ minutes.

Data on time consumed in handling buckets are as follows:

	Seconds of time: Lowering empty and lifting loaded bucket.	Rotation of crane with loaded bucket.	Dumping.	Rotation of crane with empty bucket.	Total time for handling one bucket. Min.	Sec.	Arc turned.
No. 1	43	15	13	12	1	23	180
2	45	17	8	10	1	20	180
3	60	20	10	15	1	45	270
4	38	18	14	18	1	28	270
5	37	18	12	10	1	17	200
6	50	18	8	12	1	28	200
7	62	15	10	10	1	37	270
8	43	17	15	10	1	25	270
9	44	16	10	15	1	25	240
10	45	15	20	11	1	31	240
11	42	18	19	18	1	37	270
11 buckets handled	509	187	139	141	16	16	200
Average	46	17	13	13	1	29	200

This indicates that the time required to handle one bucket is approximately 1½ minutes, so that barring delays 40 buckets of 52 cu. yd. would be the maximum hourly capacity of the crane.

The owners of the plant are much pleased with its operation and are going to give it a trial with three 8-hr. shifts.

It will be seen that the plant is of low first cost, is adapted to the handling of a variety of materials, is economical of time, and affords a great saving in the wear and tear on teams and wagons which results from hauling out of an excavation. This last point is considered by Mr. Cook to be the greatest advantage of the system.

Bottom Dump Buckets. These are more suitable for handling concrete than earth. Where present on a job for the former purpose they are often used for removing the hand excavation to neat lines. For this work they possess no advantage over skips.

Three Types of Buckets on Sewer Work. According to *Engineering and Contracting*, June 29, 1910, bucket excavation was employed in digging 2,723 ft. of the Northwestern Trunk Sewer at Louisville, Ky.

The main plant for this contract consisted of three ten-ton Browning locomotive cranes, two of which were equipped with automatic buckets. One orange-peel of 1 cu. yd. capacity and one clamshell of ½ cu. yd. capacity are used. The cranes run on standard gage track of 60 and 65-lb. rails. The track is laid along the trench for 600 ft. On account of there being plenty of good sand in the trench, it is screened and used for the concrete. The screen used consists of a framework placed opposite

to one of the cranes. This crane dumps part of the sand into the hopper at the top of the screen and the sand and rejections are carried by chutes to separate piles 15 or 20 ft. away from the trench.

In opening the trench horse scrapers were used and enough of the trench was excavated in this way, and used for filling in low land near by, to take up the amount which would necessarily have to be spoiled. An average of half a dozen teams were used on this work with one team acting as a snap team. The longest haul was about 100 yards.

Excavation and Backfill. The cranes operate about as follows: Crane No. 1 is equipped with an Owens clamshell bucket and takes out the cut to a depth of about 10 or 12 ft. The sheeting is started as soon as practicable and crane No. 2 equipped with a ¾-cu. yd. bucket takes out the balance of the cut. The cranes dump all excavated material in a spoil bank except the sand, which is dumped on the screen by crane No. 2. Crane No. 3 brings up the rear of the work and does all the backfilling and pulling of timbers and sheeting.

Progress and Costs. Progress and costs of various parts of the work are interesting. The working day is 10 hr. Crane No. 1 operates a ½-cu. yd. Owens clamshell bucket and averages 400 buckets in 10 hr. or 200 cu. yd. This bucket handles a full half yard at each operation. The labor cost on this machine is as follows:

1 engineman at	$ 3.50
1 fireman	2.00
1 tagman	1.75
1 signalman	1.75
Cost of labor for 200 cu. yd. (clay)	$88.90
Cost of labor per cu. yd., $0.045.	

The second crane handles sand in a ¾-cu. yd. dump bucket filled by hand. It handles 300 buckets or 225 cu. yd. a day. The labor cost on this is as follows:

1 engineman	$ 3.50
1 fireman	2.00
1 foreman	2.00
8 men in bottom at $1.75	14.00
Cost of labor for 225 yd.	$21.50

This gives a cost of labor for 1 cu. yd. of $0.095. The third or backfill crane operates a 1-cu. yd. orange-peel bucket and handles 500 cu. yd. of material in 10 hrs. The cost of labor backfilling is as follows:

1 engineman	$ 3.50
1 fireman	2.00
1 signalman	1.75
Labor cost backfilling, 500 cu. yd.	$ 7.25

Labor cost per cu. yd. of backfilling, $0.0145.

This crane when not backfilling, pulls timbers and sheeting. The average amount of coal used by one crane in a day is 1,200 lb. Run-of-mine coal is used at $4 per ton. About 160 gal. of water are used per crane per day. The cranes each cost $5,000 new and their annual interest and depreciation is figured by the contractor at 30%.

The average wages paid upon this work are as follows:

Superintendent, per month	$135.00
Street foreman, per month	80.00
Carpenter foreman, per month	80.00
Concrete foreman, per month	80.00
Timber foreman, per month	80.00
Team foreman, per month	80.00
Man in charge of all form work, per month	135.00
Timekeeper, per month	50.00
Water boy, per day	1.00
Stud men, per day	2.00
Carpenters, per day	2.50
Concrete men, per day	2.00
Timbermen, per day	2.00
Crane engineers, per day	3.50
Crane firemen, per day	2.00
Laborers, per day	1.75
Blacksmith, per week	20.00
Blacksmith's helper, per week	15.00
Teamsters, per day	2.00

Orange-Peel Buckets. These are made in two forms and in a great variety of sizes. The bucket with four segments is suitable for excavating loose material in which it will sink of its own weight. Where the material will not permit this, the orange-peel does not fill so well as does the grab bucket.

The second type of orange-peel bucket is made with three segments and is most suitable for excavating where rocks and logs have to be handled. It will grapple and hang on to anything that gets between its jaws. Buckets of this type are made up to 6 cu. yd. capacity, and strong enough to handle a 10-ton rock. At the other extreme of size, four segment buckets have been made small enough to clean out 12-in pipes.

Work of an Orange-Peel Bucket at Massena, N. Y. The excavation for the foundations of power house was described in *Engineering News*, Dec. 15, 1898. The work was accomplished by a steam shovel working in the pit, and a land dredge with an orange-peel bucket operating from the bank. Both machines loaded into dump cars hauled by locomotives. The orange-peel

excavator dug 35 ft. deep in very homogeneous, cheese-like, clay. With a 1-cu. yd. bucket the daily output in 10 hr. was 600 cu. yd. The total labor cost of operation was $20, giving a labor cost of 3⅓ ct. per cu. yd.

Fig. 5. Orange-Peel Bucket Made by the Hayward Company, 50 Church St., New York.

Cost of Excavating Trench with Orange-Peel Bucket. In *Engineering-Contracting*, April, 1906, a detailed description is given of the plant and methods used in building a large sewer in Chicago by city forces. For part of the work a 1 cu. yd. orange-peel bucket was used. A traveling derrick, on rollers, was used. It was designed to swing in a full circle. The crew was:

	Per day
1 engineman	$ 4.80
1 fireman	2.50
1 signal man	3.25
1 powder man	3.25
2 laborers at $3.25	6.50
Total per day	$20.30

Under ordinary conditions, the orange-peel bucket excavated about 450 cu. yd. a day, all earth being dumped on a spoil bank at one side.

On the assumption that 450 cu. yd. were excavated per day, the labor cost was 4.5 ct. per cu. yd. About 50 lb. of dynamite and ¾ ton of coal were used each 8-hr. day. The cost of the dynamite was $7.50 and the coal cost $3 per ton, making the total cost for dynamite and coal $9.75. The total cost per day for excavating thus was $30.05; and the cost per cu. yd. was 6.6 ct., exclusive of the wear and tear on the machine.

In this excavation the swinging derrick with the orange-peel bucket could be worked to better advantage than a steam shovel, inasmuch as it could work between the braces, which were 11 ft. centers. The bracing was placed as the excavation proceeded, and when the trench excavation was completed, the braces were all in place. By the use of the derrick the excavated material could be deposited far enough from the trench so as not to necessitate rehandling. In the case of a steam shovel it would have been necessary first to put in a temporary bracing, and a permanent bracing afterwards. Also, the boom of a steam shovel would not be long enough to deposit the excavated matter the necessary distance from the trench.

Cost of Excavating Sand in Trench with an Orange-Peel Bucket. *Engineering and Contracting*, July 15, 1908, gives the following. In the construction of District Sewer No. 1 for the town of Gary, Ind., built by the Green & Sons Co., of Chicago, the preliminary excavation for the first 1,830 ft. was done with a Hayward orange-peel bucket of ¾ cu. yd. capacity. The bucket

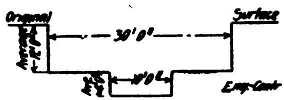

Fig. 6. Cross-Section of Cut.

was operated by a 25-hp. hoisting engine and a separate swinging engine. The machine was mounted on rollers and moved forward with its own power by means of a "dead man" ahead.

The material removed consisted of fine sand of the kind prevalent throughout the Calumet region, the last 3 or 4 ft. of excavation being in water. The cut was in cross section as shown in Fig. 6.

The crew consisted of one engineman at $6 per day, one foreman at $3.50 per day and five laborers at $1.50 per day who handled planks and rollers, built up runways for the machine

in rough ground, and smoothed up the cut and left a smooth shelf for the workmen following up the dipper. This makes a total labor cost of $17 per 9-hr. shift. The coal consumption averaged $5 per day, making a total cost per shift of $22.

The work was begun April 2 and the first 1,830 ft. were completed May 21, making 43 working days. The machine was shut down five days for repairs, and there was a night crew on for 13 additional shifts. This makes a total of 51 complete shifts.

51 shifts at $22	$1,022.00
5 days' extra pay for engineer and fireman (during repairs)	47.50
Cost of oil and extra help on repairs, about	65.00
Total	$1,134.50

The total number of yards removed was 21,250, making a net cost of 5.3 ct. per cu. yd.

Clam-Shell Buckets. These are also called grab buckets. They are made in a great variety of forms, special designs being offered by the manufacturers for almost every service. In general, an extra line besides the hoisting line is required to manipulate the bucket. However, most manufacturers are now offering buckets that operate on a single line, a hand line being used for dumping.

A single line bucket made by Edgar E. Brosius, Pittsburg, Pa., is shown in Fig. 7. It is made in the following sizes and weights:

Size	Weight
½ cu. yd.	1,200 lb.
¾ cu. yd.	2,600 lb.
1 cu. yd.	3,000 lb.
1½ cu. yd.	4,000 lb.
2 cu. yd.	5,000 lb.
3 cu. yd.	6,000 lb.

A similar grab bucket is made by the Brown Hoisting Machinery Co., of Cleveland, O. This bucket is especially useful where frequent changes have to be made from bucket to hook.

Another type of grab-bucket is handled with a single line and is equipped with a motor for opening and closing. It has the advantage of being able to dump its load gradually, an advantage not possessed by other single line grab buckets.

Grab-buckets are more suitable than orange-peel buckets for excavating hard material. The edges are frequently provided with teeth, and the scraping action of the bucket in closing, together with its weight and the great force that can be exerted, insure good filling.

The Fogarty Excavating Bucket requires an engine with two working drums, one for the hoisting line and one for the closing

line. Otherwise it can be used on any type of crane or derrick car. It is directly attached to the derrick boom instead of being suspended. This bucket is made by Rochester Excavating Machinery Co., Rochester, N. Y.

Clamshell Bucket Excavation on Boston Subway. *Engineering News-Record,* June 7, 1917, gives the following: The top 22 ft. of a timbered cut for section G of the Dorchester tunnel in Boston has been taken out with a traveler and clamshell bucket, keep-

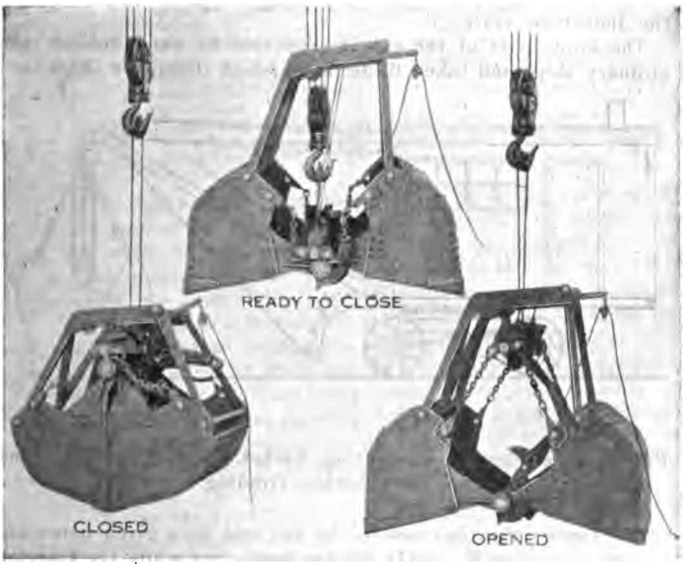

Fig. 7. Brosius Single Line Grab Bucket, Closed Position.

ing pace with two ordinary hoisting rigs removing the lower lift and requiring only a small crew for its operation. It was possible to close the street, and the traveler moved down the middle of it ahead of the cut, taking out sections 25 ft. in length at a time. The dirt was disposed of in backfill or on a rented dump by industrial cars and two small locomotives.

A large A-frame derrick has taken out the greater part of the excavation in sections the full 35-ft. width of the cut, 25 ft. long and 22 ft. deep. Although this rig is equipped with a Fogarty bucket, it does not have the extra boom generally used to bear down on the bucket and increase its digging power. This

is not found necessary, and the derrick is rigged with a three-drum engine and swinging gear in the ordinary manner.

No longitudinal braces are used in the upper part of the excavation, so that the bucket can be operated between the cross-braces freely. These are 10 x 12-in. pine timbers, spaced 4 to 5 ft. apart vertically and 10 ft. apart horizontally. The sides of the cut are held by 3-in. sheeting driven by hand or with a small air hammer. Poling boards are used on part of the westerly side of the cut, as there is not room to drive the sheeting outside the industrial track.

The lower part of the cut is excavated by hand, loaded into ordinary skips and taken to derricks, which dump the skips into

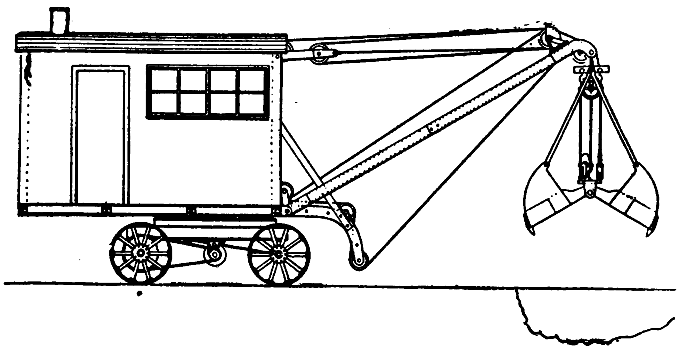

Fig. 8. The Fogarty Excavating Bucket. Note Crowding Line for Hard Surface Grading.

cars. During the time covered by the cost data given herewith, two of these derricks would fill five dump cars while the traveler was filling five more. The ten cars were then hauled to the dump or to the backfill by a locomotive. The dump, which was at one end of the job, was leased, and the industrial-railroad equipment used to reach it and the backfill comprised about 3,000 ft. of track, 25 Koppel dump-cars of 1-yd. capacity and a Koppel steam locomotive, in addition to a Plymouth gasoline engine.

The material excavated by the traveler consists of 12 ft. of gravel fill, a layer of peat and successive layers of sand and clay. One small brick sewer encountered and a larger brick intercepting sewer, which last had to be broken up with sledges, were readily removed. The crew required with the traveler consists of a foreman, an engineman, two bracers and nine laborers. This gang could remove an average of 65 yd. of material in an 8-hr.

shift. Accurate costs kept on this work for one month in January and February, 1917, indicate a direct cost of $1.47 per yd. for excavating the material and placing it in backfill, which cost slightly more than carrying it to the dump, on account of the greater labor required in spreading.

COST OF EXCAVATING WITH CLAMSHELL

Rent of equipment, fuel	$0.17
Superintendent, timekeeper, foreman	.12
Labor, engineer, bracers	.51
Repairs and incidentals	.03
Insurance	.07
Lumber (bracing and sheeting)	.12
Pumping	.09
Hauling equipment, rent, fuel	.08
Hauling, labor, insurance	.09
Lease of dump	.06
Dumping and spreading in backfill, labor, insurance	.13
Total direct cost per cu. yd.	$1.47

The figures for rental equipment given in the table assume the new cost of the entire traveler rig as $4,000, on which basis $42 per week as rent for this equipment is charged to the work continuously, whether the equipment is idle or not. The estimated new cost of the hauling equipment is $6,200, and $54 per week rental is allowed for it. Coal is figured at $6 per ton, the wages of an engineman at $4 per day, bracers at $3.20 per day, and labor at $2.25 per day of 8 hr. On this part of the work, lumber is used very economically, the bracing serving four times and the sheeting twice. Both kinds of lumber will have a large salvage value at the end of the job, and on this account $10 per M is charged for the lumber each time it is used.

During the time these data were taken, five days were lost on account of stormy and extremely cold weather, and one day on account of repairs to the derrick. The costs, of course, are increased by frost and cold in comparison with warm weather costs for the same work. Data kept during February and March on the cost of taking out about 1,400 yd. of excavation from the lower 20 ft. of the trench, the part not excavated by the traveler, indicate a direct charge of $2.39 per yd. for handling the material in the old way. Although bad weather interfered considerably with these operations and the amount excavated was scarcely enough to give average figures, the result at least indicates that the relative cost by the traveler method is much lower than in excavating by hand. Three-quarters of the whole cost of pumping is charged to the lower portion, and all the cost of the tongue-and-groove sheeting left permanently in place.

COST OF EXCAVATING SECOND LIFT BY HAND

Rent of equipment, fuel	$0.13
Supervision	.21
Labor, engineer, bracers	.92
Air, hammers, repairs	.13
Pumping	.23
Insurance	.11
Lumber left in place	.27
Haul	.17
Dumping	.22
Total direct cost per cu. yd.	$2.39

Bibliography. "Handbook of Construction Plant," Richard T. Dana.—"Excavating Machinery," A. B. McDaniel.—"Cost Data," H. P. Gillette.

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CHAPTER XIII

METHODS AND COST WITH CABLEWAYS AND CONVEYORS

Cableways properly include only those means of haulage wherein the load is suspended beneath a cable by means of a carriage whose grooved wheels run on top of the cable. Data on hauling cars by cables will be found in Chapter X.

Cableway. The term cableway was coined in order to indicate an aerial transportation machine in which the single load was hoisted as well as transported on a single strand of cable. The

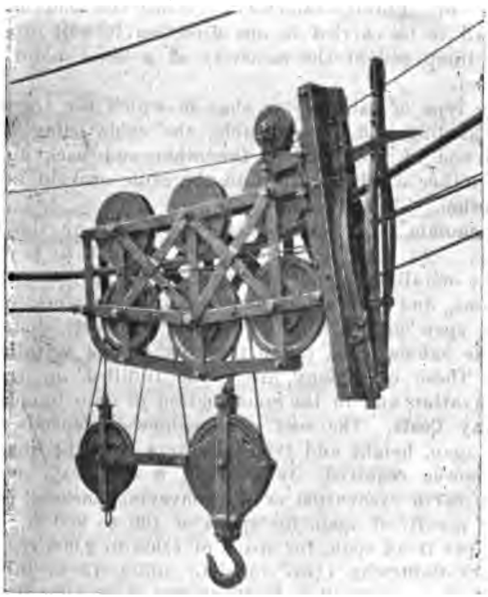


Fig. 1. Standard Cableway Carriage.

term "aerial tramway" applies to a machine in which the loads, often small and numerous, are hauled along a fixed track by a moving traction rope. On the aerial tramway the carrier may be arranged to pass the towers or other supports, and this is one of the distinctive points of difference between an aerial tramway and a cableway. In the aerial tramway the cables are tightened by means of weights or similar tension device, but in the case of the coasting or gravity cableway no tension devices are required.

A cableway consists essentially of a main cable suspended between two towers or anchorages, serving as the track for a trolley carrying the load. This load is pulled back and forth by smaller cables. Where the track cable is so arranged that the slack may be increased or diminished at the will of the operator, thereby directly raising or lowering the load, the machine is termed a "slack cableway." Similarly, when one end of the cableway can be raised or lowered so that the load may slide through gravity to the other end, the machine is termed a "coasting" or "gravity cableway." When the loads on a cableway are all to be carried in one direction it will often pay to have the dump end of the cableway at a lower point than the loading end.

Another type of cableway is that in which the track cable is also the hauling and return cable, the cable being continuous from one end of the span to the other and back again. The bucket is either firmly fastened to the cable or held in place on it by friction.

The Economic Use of cableways is limited by the following conditions: (1) A sufficient quantity of work to pay the cost of the first installation, plus the cost of ensuing removals and reinstallations, and (2) a sufficient quantity of work within the length of span and within economical reaching distance each side of the cableway to repay the cost of one installation and removal. These conditions are often fulfilled on trench and canal excavation and in the construction of dam foundations.

Cableway Costs. The cost of a cableway depends upon the length of span, height and type of towers, and the quantity and kind of power required. In general, a cableway, designed to operate in earth excavation or for conveying buckets, costs from $8 to $15 per ft. of span, for spans of 400 to 800 ft., and from $6 to $12 per ft. of span, for spans of 1,000 to 2,000 ft.

A Duplex Cableway (two complete cables, 15 to 20 ft. apart, on common towers) will cost about $11.50 per ft. of span, for spans of 2,000 ft., when the towers are from 75 to 130 ft. high.

Cableway Systems. F. T. Rubidge, in *Engineering and Contracting*, Jan. 8, 1908, gives the following: Mr. Rubidge defines an inclined cableway as one having sufficient inclination so that the power required to hoist the load is less than that required for conveying. This enables the use of a single rope for both hoisting and conveying. Where the inclination of the cableway is less than this, it is classed as horizontal, though the ends of the span may be at different levels.

Horizontal Cableways. In this system, in addition to the

cable and carriage that travels upon it, there must be provided independent means for hoisting and conveying the load.

In the case where the motor is installed upon the carriage, the latter is propelled by gearing to the sheaves traveling upon the main cable. As a cable with both ends fixed takes the approximate form of an ellipse, it would be impossible for the carriage to climb the steep part of the curve at either end. To overcome this, the bents or towers are free to move at the top in the direction of the cable and they are so weighted that the main cable is under constant tension. This causes the carriage to travel an approximately uniform grade. This device is called the Balanced Cable Crane. The fact that the cable must sustain

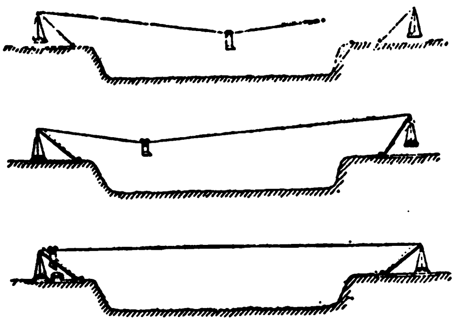


Fig. 2. Balanced Cable Crane Horizontal Cableway.

the additional weight of the motor and motorman is a disadvantage, but in many cases it is offset by the advantage of having the operator close to the points of loading and dumping.

Arrangement of Hoisting and Conveying Ropes. In cases where the engine or motor is located at the end of the span, ropes in addition to the main cable are necessary, the one for hoisting, the other for conveying. When an orange-peel or other self-filling bucket is used, a third rope and an extra drum on the engine must be provided.

Figs. 3, 4 and 5 show three different arrangements of hoisting and conveying ropes which have been adopted by the Lidgerwood Mfg. Co., the Lambert Hoisting Engine Co., and the Trenton Iron Co., respectively.

In the arrangement adopted by the Lidgerwood Co. the load is first hoisted to the desired height. During conveying, both hoisting and conveying drums must be in operation, and of the

same diameter so that the load may remain at a constant distance from the cable.

In the arrangement used by the Lambert Co., the engine drums have different diameters, the larger being the conveying drum.

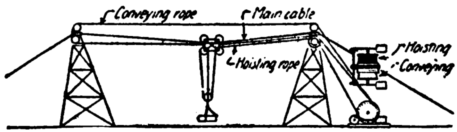


Fig. 3. Arrangement of Lidgerwood Cableway.

This permits simultaneous hoisting and conveying, and a conveying speed greater than the hoisting speed.

The arrangement used by the Trenton Iron Co. was devised to obviate the necessity of using carriers to prevent sagging of the hoisting rope. The hoisting rope is attached to an endless

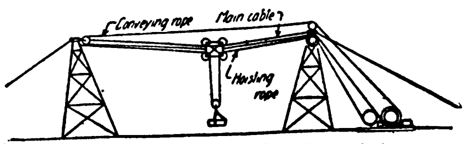


Fig. 4. Arrangement of Lambert Cableway.

rope at the point A by means of a specially constructed swivel connection. The endless rope is passed a number of times around an elliptic-faced drum, to give sufficient friction for hoisting the load. In operation both hoisting and conveying drums are in motion during conveying, and both must be of the same diameter.

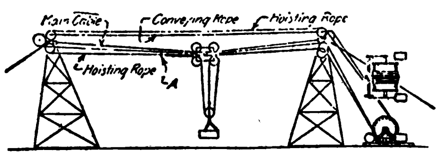


Fig. 5. Arrangement of Trenton Iron Co.'s Cableway.

Fall-Rope Carriers. The economical operation of a cableway depends in no small measure upon the carriers employed. Their function is to prevent excessive tension (due to sag) in the hoisting rope, so that when the load is detached from the fall-

block, the latter, while free, will not ascend to the carriage. Even with the use of carriers it is necessary to use a weighted fall-block, so that it may be raised or lowered by the engineman when no load is attached.

The following are styles of carriers in use:

(1) *Chain-Connected Carriers.* These consist of a supporting sheave which travels upon the main cable, below which, in the same frame, are sheaves for the support of other necessary ropes. The side plates which form the frame for the sheaves must project beyond them, so that when adjacent carriers strike each other the sheaves will not come into contact. The connected

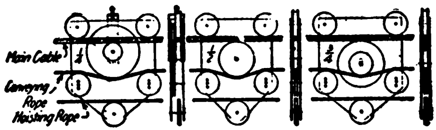


Fig. 6. Lambert-Delaney Carrier.

carriers are attached at one end to the lower and at the other to the carriage. When the carriage is close to the head tower (engine end), the carriers are all in contact with the chains hanging in loops below. As the carriage moves toward the tail tower the carriers are spaced along the cable with the chains hanging in festoons below.

(2) *Button-Rope Carriers.* With this carrier an additional rope across the span is required. It is fixed at one end and kept at a constant tension by a weight at the other. At intervals along the rope are affixed "buttons" with a gradation of diameters, the smallest being the first from the head tower. The carriers are provided with eyes having a corresponding gradation of diameters, slightly smaller than the buttons, through which the button rope is threaded. The carriage is provided with a projecting arm or "horn," which picks up the carriers as each is met during the travel of carriage toward the head tower. All the carriers are riding upon the arm when the head tower is reached. On moving away from the head tower, the first button passes through the eyes of all the carriers but the last. This one is snatched from the arm and deposited upon the cable. The second button selects the next carrier, and so on.

(3) *The Lambert-Delaney Carrier.* This is rather an ingenious device, depending upon the fact that points along the vertical diameter of a horizontally rolling wheel travel at different velocities. The rolling wheel in the case of the carrier is inverted,

and rolls upon the under side of the main cable. The conveying rope is the rolling force, and is applied at different distances from the center of the rolling sheave to obtain the required variation in velocity of travel. Fig. 6 illustrates the construction. It will be noticed that, in the quarter speed carrier, a yoke with set screw is used to increase the friction between the rolling sheave and cable.

The advantages and disadvantages of the above types of carriers are as follows:

Chain-connected Carriers. Advantages: (a) Simplicity. (b) Not easily deranged. (c) Positive spacing. Disadvantages: (a) Extremely heavy. (b) Considerable wear. (c) Power required to stretch chains as carriage nears tail tower.

Button-rope Carriers. Advantages: (a) Extremely light. (b) Minimum wear to both carrier and cable. (c) Positive spacing. Disadvantages: (a) Maintenance of button rope.

Lambert-Delaney Carriers. Advantages: (a) Neither rope nor chains required for spacing. (b) Weight of carriers uniformly distributed at all times between carriage and towers. (c) Moderate weight. Disadvantages: (a) Double bending of conveying rope while passing through carriers, causing short life of rope. (b) Variable spacing due to slip between rolling sheaves and cable. (c) Large number of sheaves to maintain.

The arrangement shown in Fig. 5 is "the Laurent-Cherry" system, which employs no carriers, as above mentioned. The advantages are: (a) A minimum of working parts not easily accessible. (b) A minimum of dead weight to be sustained by cable. The disadvantages are: (a) The endless hoisting rope is subject to considerable wear owing to constant slipping on elliptic-faced drum. (b) When hoisting from a considerable depth below the main cable and conveying toward the tail tower, there is a limit to the distance of approach to the tail tower, owing to the fact that connection at *A*, Fig. 5, cannot pass over the tail tower sheave. On this account a greater span is necessary under such conditions than in the other arrangements.

The Incline Cableway. It is obvious that when the inclination of the cable is such that greater power is required for conveying than for hoisting, the carriage will remain stationary on the cable while the load is being hoisted, even though no conveying or endless rope is used. Should the load be hoisted until the fall-block comes into contact with the carriage, the further pull on the hoisting rope will cause the carriage with the load to move along the cable. A single drum engine is, therefore, all that is necessary.

The simplest form of incline cableway is used where the load-

ing is always done at the same point, also the unloading. In this case a stopping block is clamped to the main cable to prevent the carriage running below the point of loading, and a self-engaging latch is clamped to the cable at the unloading point to hold the carriage in position while the load is being lowered for unloading.

Where it is necessary to provide means for loading and unloading at any point, an endless rope is used as in the horizontal cableway, but no power is necessary for its operation, its function being merely to hold the carriage at any desired point. This is accomplished by passing the endless rope a number of times around an elliptic-faced drum provided with brake only.

The Aerial Dump. The range of the cableway is largely increased by the possibility of dumping the contents of the skip at any point in its travel by the manipulation of a lever at the engine. The skip employed has an open end, so that tilting is all that is necessary for dumping. The skip is suspended from the hook of the fall-block by chains with hook ends attached to the sides and ends of the skip. The end of the skip is also attached to another fall-block reeved with the dump line. The latter necessitates two additional sheaves below the cable in the carriage, and is reeved in a manner similar to the hoisting rope. In the Lidgerwood self-dumping device the dump line is wound on the hoisting drum, and when it is desired to dump the skip, the line is shifted by a suitable mechanism upon an increased diameter of drum. This causes the dump line to be drawn in at a higher rate of speed than the hoisting rope, and results in the tilting of the skip for discharging the contents.

In the Lambert system the dump line is attached to its own drum mounted on a shaft with the hoisting drum, in close contact with the latter and so arranged that the hoisting drum, when released with a load, can make only a half revolution while the dump line drum is stationary. During hoisting, the hoisting drum drives the dump line drum and, both being of the same diameter, the skip remains horizontal. When it is desired to dump the skip, the brake is applied to the dump line drum and released on the hoisting drum.

Lubrication. The fact that the sheaves in the carriers, carriage, and tops of towers are not easily accessible renders self-lubricating bushings desirable, and they are generally used. Their use, however, does not mean that little attention is required. The carriage and hoisting rope especially should be carefully examined daily, for, while the apparatus is seldom used to transport men, the load is generally conveyed above them.

Towers. Either tower may be fixed or movable. When both

are movable the tracks must be parallel. The parallel track arrangement was used extensively in the excavating of the Chicago drainage canal. A common arrangement is the radial cableway, where one tower is fixed and the other movable.

Movable towers are usually mounted on standard railroad wheels. The track consists of six or seven lines of rails, and rail braces should be used plentifully. Power for moving the tower may be obtained from the winch-head on the cableway engine, or, if the tower must be moved often, a special engine is provided. Movement is accomplished by block and tackle between the engine and anchorage at either end of the track. Considerable power is necessary on account of the large amount of friction between flanges of wheels and rails.

For low towers in fixed positions the "A" frame is commonly used, but the head tower should not be so low, or the engine so close to it, that the fleet angle of the ropes becomes excessive. In some cases, especially in incline cableways, the tail tower may be dispensed with and a rock anchorage substituted. High towers are common where height is desired for disposal of material beneath the cable, and in very low spans where the deflection of the cable is necessarily large. They are usually constructed of wood, for the reason that the cost is less and in most cases they will last as long as the cableway is required. The base of the tower is usually from one-third to one-half the height. Steel masts are sometimes used for tail towers. They require at least three strong and well anchored guy lines. The base has a ball and socket joint of steel castings, and the customary wood saddle is bolted to the top for the main cable.

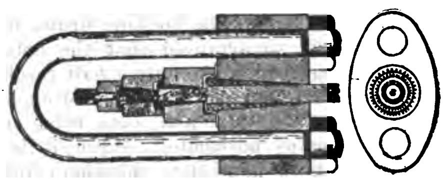


Fig. 7. Step Socket for Main Cable.

Main Cable. The essential features of the main cable are strength, lightness, flexibility, and a surface which will not only receive the least wear but impart the least wear to the sheaves rolling upon it. The standard hoisting rope is objectionable from the standpoint last mentioned. Though less flexible than the hoisting rope, the locked-wire rope is generally used for the reason that the other qualities are possessed to a much greater degree.

Fig. 7 shows the socket used on the locked-wire rope. There are six wedge segments in each cone, with the exception of the smallest, which contains four.

Means are provided for taking up the main cable when the deflection has become excessive, due to stretching. In short spans a turnbuckle is inserted in the sling which passes around the anchorage and thence through a sheave attached to the end of the cable. For long spans, special double or triple sheave blocks are used, reeved with wire rope. The take-up is usually located

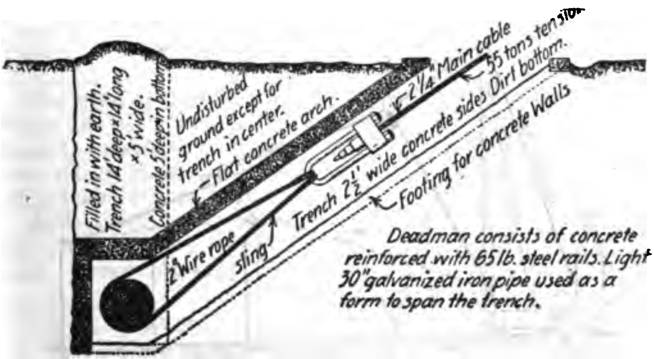


Fig. 8. Concrete Anchorage for Main Cable.

at the head tower end so that the engine may be utilized when taking up is necessary.

Anchorages. The tension of the main cable is usually from five to six times the load, depending upon the deflection. Anchorages secure beyond all possible doubt, are essential, as their failure would prove disastrous to the cableway and imperil the lives of men. Since it is impossible to calculate the resistance offered by the earth to a buried anchorage, it is usual to find a much stronger anchorage than is necessary. The usual form for moderate tensions — say up to 30 tons — is a well tarred oak log about 18 in. in diameter and 16 ft. long, buried to a depth of 8 or 10 ft. If longer life is desired, or if the tension is greater, a concrete anchorage may be substituted. A form which has been successfully used is shown in Fig 8.

A Coasting Cableway. This is a simple device of the nature of a cableway in which a line, starting at a point about on a level with the base of a pile driver or derrick is run over a sheave at the top of the leads or mast and down to the engine

drum. A snatch block travels on this cable. A tag rope is fastened to this block and may be controlled by snubbing around a post or a winch or drum on the engine. Heavy loads can be moved easily by raising or lowering one or both of the lines, as illustrated in Fig. 9.

The author has used this device on a small job for handling heavy timbers and pile caps. A floating derrick was utilized for the same purpose in the construction of the pile foundation for a large sewer in New York (see *Trans. Am. Soc. C. E.*, Vol. 31, p. 673). It may be adapted for moving earth.

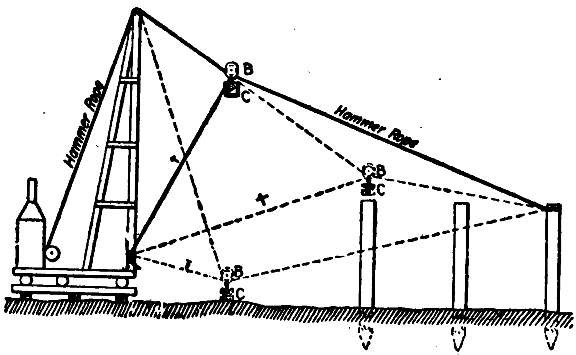


Fig. 9. Coasting Conveyor.

Parker and Flynn used an inexpensive cableway for constructing concrete piers at Northumberland, New York. This device was illustrated by them in *Engineering News*, June 26, 1902. It consisted of a 55-ft. guy derrick, without boom, placed near the edge of the bank at the side of the river, and a two-legged bent placed in the middle of the river. The cable was of ¾-in. steel and was stretched from a dead man on the shore about 150 ft. back of the derrick, past and just crossing the derrick to the bent. Under the top of the bent at the end of this cable hung two weights which consisted of scale pans loaded with concrete. In passing over the bent the cableway was carried on a 16-in. block. The boom fall of the derrick was then hooked onto the cable at the foot of the mast. The carriage on the cable consisted of two 16-in. cable-sheaves with iron straps, forming a triangle, and carrying a chain on which the bucket was hooked. In operation the bucket was hooked to the carrier on shore, a single drum hoisting engine wound up the boom fall and the cable

was hoisted until it had a pitch down toward the river of 18 or 20 ft. in the span of 450 ft. The loaded bucket travelled under gravity away from the shore. After the bucket had been dumped the boom fall was lowered until the cableway had a reversed pitch of 18 or 20 ft., when the empty bucket returned to the shore.

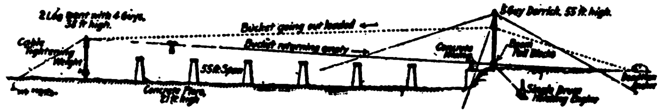


Fig. 10. A Cableway for Conveying Materials in Building Concrete Piers, at Northumberland, N. Y.

The speed of the bucket was governed by the slope of the cable. When the cable was at its extreme grade the bucket would run from the platform to the bent a distance of 450 ft. in 35 seconds and return in about the same time. This device might be employed for earth excavation.

A Balanced Cable Crane. *Engineering and Contracting*, Nov. 13, 1907, gives the following: This cableway was installed at a coal storage plant at Watertown, N. Y. It is equipped with

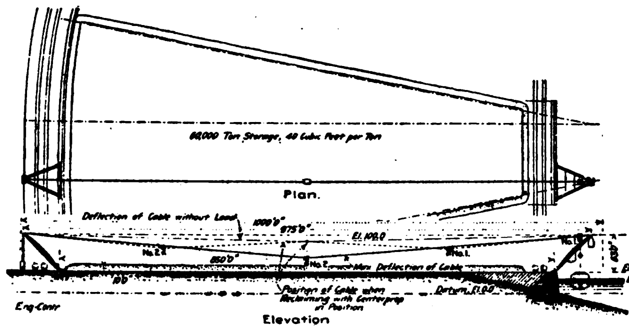


Fig. 11. Cableway in Which Sag in Cable is Practically Done Away with by Oscillating Towers.

electric motors not only on the trolley or carriage, but also on each of the oscillating towers. In this manner each tower can be propelled along the single rail track. It is not necessary that the two towers move simultaneously. Indeed, one tower can travel 25 ft. without moving the other tower. The towers have a traveling speed of 43 ft. per min., when it is desired to shift them.

The electric load carriage, or trolley, handles a 3-cu. yd. clamshell bucket, and has a traveling speed of 1,500 ft. per min. and a hoisting speed of 80 ft. per min., with a 60-hp. motor.

It is interesting to note that this cableway as built commands about 9,000 cu. yd. of material per ft. of depth. It might easily be economical equipment to use on an excavating job.

A Combination Cableway and Derrick. *Engineering and Contracting,* Feb. 24, 1909, gives the following:

Today the use of cableways for building sewers is rapidly increasing, as is also the use of portable derricks. With both machines good work can be done both in excavating the trench and in placing materials in the construction of the sewers. On this page we illustrate a combination cableway and derrick designed for spans up to 500 ft., that promises to find a great field of

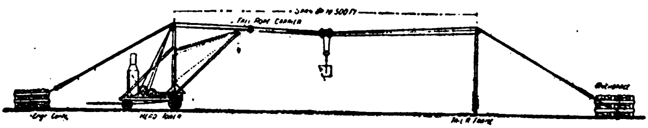


Fig. 12. Combination Cableway and Derrick.

usefulness in not only building sewers but in many other classes of construction.

The general plan is extremely simple. The derrick is built on a car with a hoisting engine and boiler. Over the A-frame for the derrick is erected a head tower for the cableway. A tail tower is erected at the other end of the work and the cableway strung and anchored to dead men as shown. In moving the cableway, only the tail tower need be taken down.

It is possible to use both the derrick and cableway at the same time, or work can be carried on with either. This arrangement means a saving in time in carrying on work. This design was gotten up by the New York Cableway & Engineering Co., 2 Rector St., New York.

Life of Main Cable. A ¾-in. wire cable used on an incline on the Chicago Main Drainage Canal lasted from 100 to 160 days, during which time it made from 30,000 to 50,000 trips, carrying from 50,000 to 80,000 cu. yd. of solid rock. Assuming the rock to weigh 4,300 lb. per cu. yd. the life of the cable was from 108,000 to 172,000 tons.

A Telpher System. *Engineering and Contracting,* Oct. 18, 1916, describes a method of disposing of subway excavation in New York City, by telpherage.

The power for hoisting and trolleying was furnished by a 60-hp. 250-volt direct current motor. A Lidgerwood 2-drum hoist was used for hoisting and trolleying. The car was a home-made affair, composed of four standard cast iron wheels 8-in. in diameter, which run on two 18-in. I-beams. These wheels supported two standard cast iron sheaves, 16-in. in diameter, through which the hoisting cable ran. The cables were arranged as shown in Fig. 13. Steel buckets and skips were used for handling material, the former holding about 1 yd., the latter 2 yd. of material.

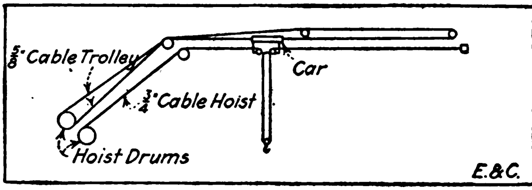


Fig. 13. Arrangement of Cables for Telpher System.

A Skip Dumping Device. This was developed in connection with the Ashokan Reservoir work of the Catskill Aqueduct and is described in *Engineering and Contracting*, Nov. 9, 1910. The cableway used was of the Lidgerwood type and was equipped with Locher skip dumping mechanism.

As shown in Fig. 14 the dump line and the hoisting rope are wound on the same drum *C* in the cableway tower and all their motions coincide. The dump rope, at the tower, runs down through a fall block *A*, then up over the sheave *B*, and thence to the main drum *C*. By pulling down the fall block *A*, which is suspended in the loop of the dump line, this line is shortened, lifts the rear of the skip and thus dumps it. It is the method of pulling down this fall block with which is novel. The old method was by a cable which wound upon a small drum. This method worked well, but was slow. The new method consists in pulling down the fall block by means of a cable which is fastened to the block and passes from there through a stationary sheave *D* directly below, thence through a sheave *E* fastened to the end of a piston rod, operated by a compressed air cylinder about 12 x 72 in. in size and thence back to a stationary anchorage *F* on one of the heavy timbers of the tower. By passing the cable through the sheave *E* on the end of the piston the distance through which the piston acts is only one-half the distance through which

the fall block is moved. The piston is operated by compressed air which is used for operating all the machines in the work.

Drag Line Cableway Excavators. These machines consist of a bucket carried on an over-head or track cable and a drag or load line. The machine is operated and controlled, as a rule, by a double-drum hoisting engine. One end of the track cable is securely fastened to a suitable anchorage, and the other end is supported by a tower, in the case of a slack or gravity cableway.

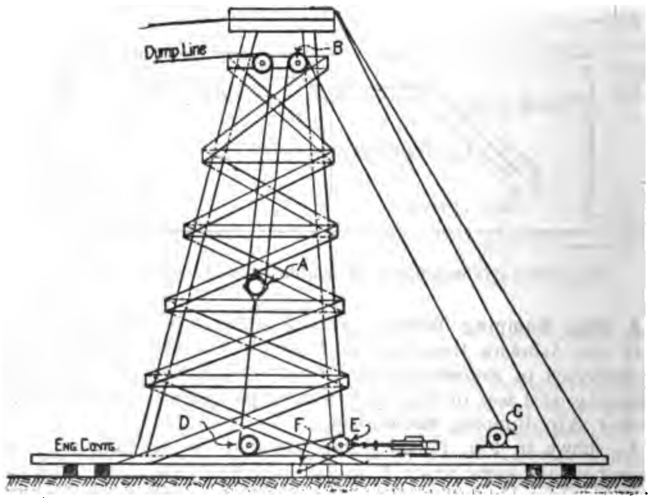


Fig. 14. Skip Dumping Device for Cableways.

The track cable can be pulled taut or slackened by means of a set of buck lines, leading to a drum on the engine. The drag line leads from the bucket over a sheave on the tower to the buck drum on the engine.

In operation, the bucket is lowered into the excavation by slacking the cables, and is then drawn forward until filled. While the bucket is loading, the track cable remains flat. As soon as the bucket is loaded, the operator gradually tightens the cable and at the same time hauls in the load by the drag line, so that the bucket is lifted and pulled to the dumping point simultaneously. The empty bucket returns to the loading point by gravity, the operators simply release the friction of the load-line drum.

The foregoing explanation applies to a flat cableway, in which

the empty bucket is lowered by gravity. In some installations it is desirable to have the loaded buckets operated by gravity.

The capacity of a cableway excavator depends on many factors, among which may be included the working span and depth, the available power, the nature of the material, and whether it is dry or wet, as well as the efficiency of the labor. Mr. W. H. Wilmn, in *Engineering Record*, June 5, 1915, states that a 1-yd. machine, working either wet or dry gravel, on an average span of 500 ft., and to a depth of about 35 ft., has easily averaged 35 cu. yd. of material per hour excavated, and carried to the top of a plant 60 ft. high. A 1½-yd. machine, operated by a 10 x 12-in. engine, under similar conditions, has averaged 50 cu. yd. per hr. Under ordinary working conditions, taking into consideration all the delays, a 1-yd. machine should average from 200 to 250 cu. yd., and a 1½-yd. machine 350 to 400 cu. yd. per day.

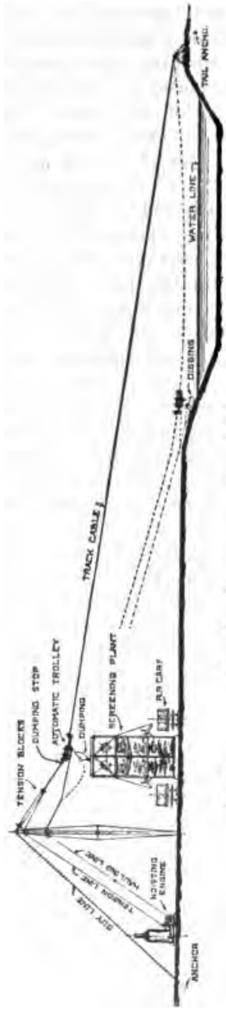
Under favorable conditions, and on usual spans of 400 and 500 ft., a load line should have a life of about 20,000 cu. yd., and a tension line should give greater service, averaging about 25,000 cu. yd. The track cable should average about 50,000 cu. yd.

Figs. 15 and 16 shows various arrangements of cableway excavators made by J. C. Buckbee and Co., Chicago, Ill.

A Cableway Scraper Excavator. *Engineering and Contracting* gives the following in the issue of Apr. 23, 1913.

A new modification in cableway scraper excavators is illustrated by the accompanying sketches. This excavator will work under water as well as in dry pits and has been quite widely employed in stripping, in gravel pits and in other loose soil excavation. The records given later indicate its economy of operation.

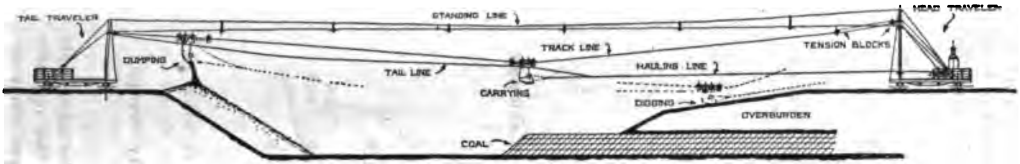
In general the plant consists of a track-cable on which runs a carriage operated by a hauling rope and carrying suspended a scraper bucket. The track cable has an adjustable attachment at one end to a mast and is at the other end fastened by a bridle hitch to two anchors. By means of this adjustable mast connection, the track cable can be slacked to lower the bucket into the pit to dig, and then made taut to raise the loaded bucket out of the pit and provide a track cableway for hauling the load to the pit bank to be discharged. The line of the track cable, being from the mast top on one side to the bridle hitch at ground level on the other side of the pit, is inclined, so that the bucket returns by gravity when the hauling rope is slacked. In brief, then, the operation is as follows: The bucket being at the pit side farthest from the mast, the track cable is slacked to lower the bucket to the pit bottom. A pull on the hauling rope draws the bucket ahead and it scrapes up a load. The track cable is then hoisted taut and raises the bucket out of the pit. The loaded



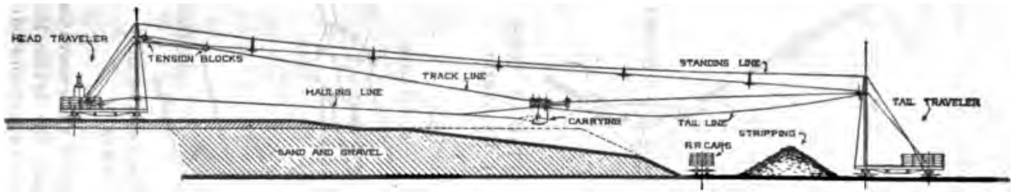
Stationary machine for digging gravel and delivering to head of screening plant

Stationary machine for removing and piling over-burden.

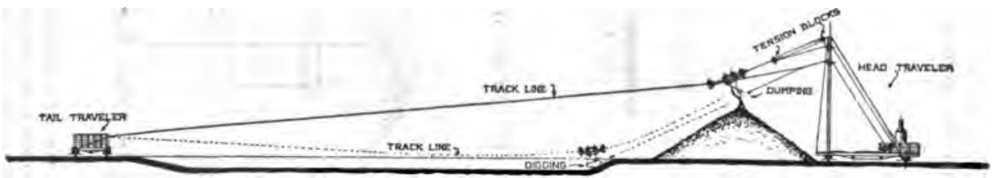
Fig. 15. Various Arrangements for Stationary Cableway Excavators.



Travelling machine for stripping coal etc.



Travelling machine for loading sand and gravel into railroad cars. Also arranged for stripping deposit.



Travelling machine for stripping or building levees.

Fig. 16. Various Arrangements for Travelling Cableway Excavators.

bucket is then hauled up the track cable to the dumping point where it is dumped automatically. The bucket then returns by gravity to its first position of readiness to excavate another load.

From this general statement it will be seen that the essential

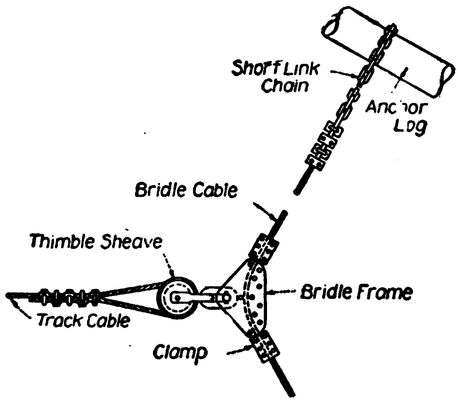


Fig. 17. Bridle Hitch for Tail of Track Cable. Cableway Scraper Excavator.

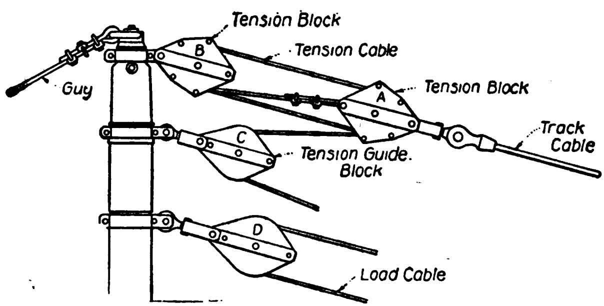


Fig. 18. Mast Top and Sheave Assembly Cableway Scraper Excavator.

structural and operating parts of the excavator are the adjustable attachments at the mast head, the bridle hitch at the opposite end of the track cable and the bucket and carriage and their operating lines. The bridle hitch is simple and is completely explained by Fig. 17. Fig. 18 shows the mast head attachment

which is explained as follows: From the rear drum of a double drum hoist at the mast bottom a tension line runs to the mast top and is fastened to the track cable block *A*, Fig. 18, after being rove as shown through blocks *B* and *C*. Block *C* is fastened in a fixed vertical position to a collar ring which is free to revolve around the mast, but the other blocks have ordinary swivel connections. The tension line, as its name indicates, is employed to make the track cable alternately slack and taut.

Turning now to the bucket hauling and dumping operations, it is noted, first, that from the front drum of the engine a line runs

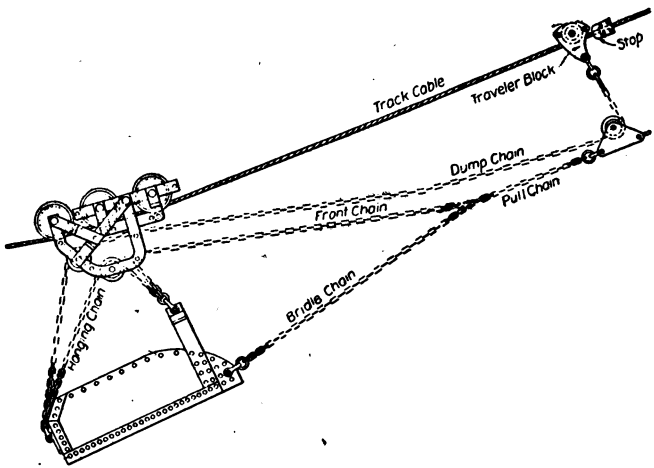


Fig. 19. Carriage and Bucket and Operating Attachments Cableway Scraper Excavator.

to block *D* on the mast, Fig. 18, and thence to the dump block to which the bucket pull chain is attached as shown by Fig. 19. This line, called the load cable, hauls the bucket on its carriage along the track cable. Fig. 19 shows the bucket and carriage and their various cable and chain attachments. The purpose of all these parts is clear from the drawing except possibly that of the dump chain. In traveling along the track cable the carriage and the traveler block keep in the relative positions shown until the dumping point is approached. Then the traveler block is arrested by a stop on the track cable, but the carriage and bucket continue on until a loop is taken up in the dump chain sufficient

to elevate the rear end of the bucket and dump the load. The relative adjustment of the bridle and push chains determines the digging angle of the bucket.

A number of this type of cableway scraper excavators are in use. The following figures are furnished of the cost of operation of one plant which is installed at a gravel pit:

Engineman	$3.00
Fireman	2.00
1½ tons coal	3.50
Oil, waste, etc.	0.50
Total	$9.00

This cost is for a 10-hr. day. A 1-cu. yd. bucket is used and about 300 cu. yd. per day are handled. On this basis the cost is 3 ct. per cu. yd., not including overhead expenses, shifting, etc. The machine is known as the Shearer & Mayer Patented Dragline Cableway Excavator. It is sold by Sauerman Bros., Chicago, Ill.

The Cost of a Tower Scraper Excavator. *Engineering and Contracting*, Oct. 26, 1910, gives the following: This cableway rig was used to operate a 48-cu. ft. bucket on the New York State Barge Canal construction. The greater part of the cost of this plant is in the hoisting engine and scraper bucket, both of which would have considerable salvage value.

The total cost of the plant was:

5,080 ft. B. M. lumber at $38 per M.	$ 193.04
360 ft. B. M. white oak at $45 per M.	16.20
540 lb. iron bolts and nuts at 6 ct.	32.40
120 ft. ⅝-in. wire rope backstays	13.20
2 ⅝-in. turnbuckles	.80
1 headblack sheave and bearing	10.00
1 hauling sheave and bearing	4.00
1 8¼ x 10 Lidgerwood double drum hoisting engine	1,089.00
1 scraper bucket, complete with cutting edge, sheaves, etc.	300.00
Labor erecting based on condition in Northern New York, carpenters at $2.50 per 8-hr. day	200.00
Total	$1,858.64

The following is an estimate of the operating cost of the plant, also furnished by the Atlantic, Gulf & Pacific Co.:

Wire rope	$160.00
20 tons coal at $4	80.00
Oil, waste and repairs	15.00
Total per month	$255.00

To this is to be added the labor cost. Each shift requires the following force:

1 foreman at 37½ ct. per hr.	$ 3.00
1 engineman at 37½ ct. per hr.	3.00
1 fireman at 22 ct. per hr.	1.76
1 signal man at 25 ct. per hr.	2.00
5 laborers at 20 ct. per hr.	8.00
And an additional	
4 laborers at 20 ct. per hr.	6.40
Total labor per day	$24.16

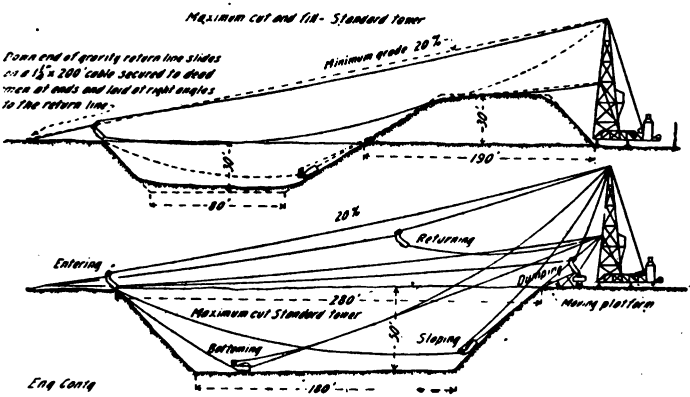


Fig. 20. Operation of Field Tower Excavator.

Assuming 26 working days and two shifts per day, the labor cost for one month is $1,256.32 which, added to $255 given above, makes a total cost for operation of $1,511.32. Assuming interest on plant at ½% per month we have an additional $9.30, making the grand total $1,520.62.

Costs with a Scraper Bucket Cableway. Detailed description and illustrations are given in *Engineering Record*, Dec. 22, 1894, of a cableway handling a scraper-bucket at Niagara Falls, Ontario.

The plant consisted of an overhead Lidgerwood cableway system carried on towers operated by a simple double-drum 8 x 10-in. engine and a boiler, and carrying a scraper-bucket for digging, lifting, carrying, and loading sand.

The operating expense per day, with an output of 400 cu. yd., was as follows:

	Per day
1 engineman	$2.50
1 fireman	1.50
1 bucket-man	1.75
1 breaking down man	1.50
1 foreman	2.50
½ ton of coal (swept from cars)	0.00
Total operating expense	$9.75

Cableway Operation in Cecila Slough. Through the courtesy of Lt. W. H. Bixby Corps of Engineers U. S. Army, I am en-

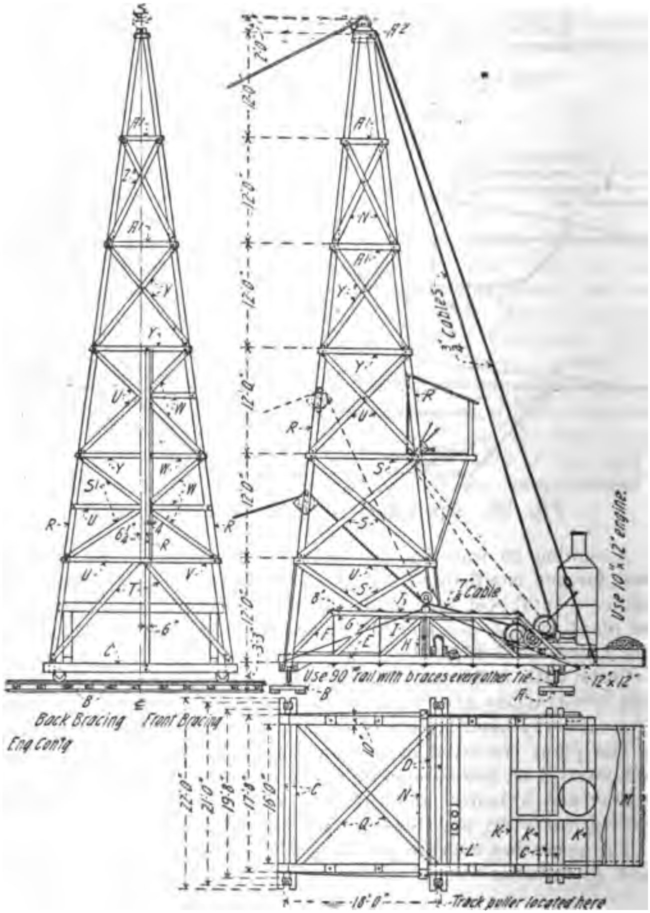


Fig. 21. Details of Tower for Field Tower Excavator.

abled to publish the following report, submitted to him by Joseph Wright, on the operation of a cableway in Cecila Slough, Ill., from Oct. 10 to Dec. 20, 1904.

This period was chosen because it is thought to be more nearly representative of what might be expected of such a plant working in soft material under normal conditions, provided that allowance be made for extraordinary breakages and renewals mentioned below:

Span of cableway	625 ft.
Average length of haul	200 ft.
Distance advanced each day by cableway about	70 ft.
Material excavated	Peat
Capacity of dippers used, 1½ cu. yd.	Nominal
Actual average dipper load, 1-77/100 cu. yd. place measure.	
Total operating cost, Oct. 10 to Dec. 20	$11,546
Total yardage	131,414 cu. yd.
Operating cost per yd.	8.78 ct.
The operating cost consists of	
Total cost of labor	$7,261
Repairs, renewals, lubricating oil, kerosene oil for Wells lights, waste, etc.	$3,528
Coal	$757

The above figures were taken from my books. It will be noticed that the item for repairs, oil, etc., is quite large. The item includes $1,350 worth of new cables, whereas only about one-third of it should be properly charged to the operating cost for this period. The kerosene oil bill for lights was about $293, or about $126 per month. This, of course, is a proper charge if operated 24 hr. per day as was the case.

Running over the journals and cutting out such items as should not have been charged to operating cost during this period, but which should have been carried as unexpended to a later period, I find an aggregate of $1,793, which should be properly deducted from the "repair" item above. Making this deduction reduced the "total operating cost" to $9,753, and the "operating cost per yard" to 7.42 ct.

It is only fair to state in this connection that during the period of operating for which cost data are submitted, the towers were moving over very soft ground. This made the track work expensive, and was the cause of a number of extraordinary breakages. Then, too, 3 crank shafts of the cableway engines were broken and renewed during this period, due to the engines having been provided with unsuitable foundations when installed. The cost of the new shafts has been included in the deduction made above, but the cost of the delay occasioned has not. The engines were taken up and re-bedded during the winter of 1904 and 1905, and since have given no trouble by breaking shafts or heating of journals.

Numerous other improvements, renewals, etc., were made at the same time, among which was the substitution of 2-in. patent locked main cables for the old 2¼-in. cables. This change alone

resulted in the saving of $180 per month on carriage sheaves during the season of 1905 as compared with the period chosen.

The number of buckets handled each day was registered by the bell boys.

The cost given includes the cost of a large force of ditchers employed during the entire year, and the extra expense entailed by the necessity of having to move across the slough four times instead of once. The material was so unstable it was necessary partially to excavate the cut in passing over it the first time, ditch it, let it dry, and then pass over it again, repeating the process until the cut was excavated to grade. Then there was the cost of lengthening the span from 525 ft. to 625 ft. and many other things, which, while properly charged in our records, it is unfair to charge to the cableway when compared with other excavating machines.

During the period for which data are submitted in this report, the cableway was passing through the slough the first time and the cut was being excavated from 8 to 10 ft. deep. The rate of track laying was about 70 ft. per day. Had the cut been deeper the output would, of course, have been somewhat larger, and the labor account on track work materially smaller.

The operating force required, and the wages paid were as follows:

1 engineman	$125.	per mo.
who had charge of the machinery, and who slept on the ground, took his turn at the operating levers for eight hours each day, and who was subject to call at any time in case of a breakdown.		
5 enginemen (8-hr. day)	$ 4.00	per day
6 firemen (2 for each shift)	2.50	" "
3 riggers (1 for each shift)	2.00	" "
3 pumpmen (1 for each shift)	1.60	" "
2 light tenders (1 for each night shift)	1.60	" "
6 signal men (2 for each shift)	45.00	" mo.
1 foreman (day shift only)	75.00	" "
12 to 16 laborers (day shift only)	1.60	" day
2 and sometimes 3 teams (day shift only)	3.50	" "

The above list constituted the operating force, but in addition a part of the salaries of Junior engineer ($130), Surveyman ($60), Timekeeper ($60), Locomotive engineer ($90) and Fireman ($60), Blacksmith ($2.50) and locomotive rental were apportioned to the work.

Nothing was allowed for interest and depreciation, but the plant cost complete and in operating, $28,580, and a proper charge for depreciation could be arrived at when the yardage to be handled on a particular job is known.

A Record of Cableway Efficiency. *Engineering and Contract-*

ing, Aug. 10, 1910, says that a letter of endorsement recently given by a high official of the Isthmian Canal Commission to the operator who had charge of the eight Lidgerwood Cableways used in building the Gatun Locks during the preceding eleven months contains incidentally a remarkable record of efficiency of the cableways. This passage reads as follows: "These cableways so far as delays from breakage or repairs were concerned, while working 12½ hours per day, have been kept up to an efficiency of 99 per cent." That is to say, that during this whole period only 1% of time was lost on account of making repairs. The cableways referred to are eight of thirteen designed and built by the Lidgerwood Mfg. Co. for the Isthmian Canal Commission. These eight cableways are for building the locks and are used for placing the concrete and reinforcement and also for handling forms. They are travelling cableways of 800 ft. span, operated electrically. They are handling on every working day more than 3,000 cu. yd. of concrete.

Cableway and Grab Bucket. The following is from a paper by E. H. Baldwin in *Engineering News*, Jan. 14, 1915. In excavating the foundation of Elephant Butte Dam near Engle, New Mexico, three cableways, each 1,400 ft. long and of 45-ton capacity, located 60 ft. apart, were used to operate 3-cu. yd. clam shell buckets. The cableway engines were 300 hp., with a hoisting speed of 200 ft. per min., and a travelling speed of 800 ft. per min. The height of the cables above the deepest part of the excavation was 350 ft.

The material was sand and gravel. At first it was picked up by the buckets without "tagging," but it soon became necessary to pull the buckets to side points by tag lines operated by 2 or 3 men. This method consumed much time and several 2-drum electric hoists were substituted for the hand work. Shortly after shale and limestone were reached, skips were substituted for the buckets, but in loose material the buckets worked efficiently. The loading time was short as compared with the travelling time, so full buckets were insisted upon.

The best output was 1,817 cu. yd. for 3 cables in 3 shifts of 8 hr. each, 722 cu. yd. for 3 cables 1 shift, and 288 cu. yd. for 1 bucket 1 shift.

A Derrick Trolley. *Engineering News*, Jan. 27, 1916, gives the following:

In digging the lock pit for the Sabine-Neches guard lock in Texas, caving banks necessitated considerably more excavation than had been expected. The dumping area proved insufficient, and the weight of the deposited material caused further sliding of the banks. As the amount of material to be excavated was not

sufficient to justify the purchase and erection of a cableway or additional derricks, the derrick on the job was rigged with a trolley line, as illustrated in the sketches.

The rigging of the load line is the same as for ordinary hoisting (see Fig. 22). The trolley line is carried on the middle drum and runs through a sheave in the bottom of the mast, thence through a sheave in the end of the boom, then around the bottom of a sheave in the steel block, and the end of the line is made fast to the top of a ginpole. The boom line is carried on the front drum, and is rigged the same as for ordinary derrick work. All lines are of 5/8-in. wire rope.

The material box is a 1-yd. open-end skip. The ginpole, or tail tower, 26 ft. high, is of yellow-pine piles, old hoisting rope being used for guys.

This trolley-line arrangement has been operated for a distance of 300 ft. with a 12-ft. drop. Experience shows that a load of at least 2,500 lb. is necessary to operate the trolley on this flat slope. In very soft, wet ground, with a gang consisting of a foreman and five men filling the skips, a foreman, a hoisting engineer, and a laborer to dump the boxes, 137 skips were moved in 8 hr. In harder digging, where it was necessary to load the skips with shovels instead of by bailing, 70 skips were averaged in the same period.

Excavation Cost with Cableway, Hennepin Canal, Ill. The Lidgerwood Mfg. Co. furnishes the following data:

The Hennepin Canal at one point has a bottom width of about 52 ft., side slopes of 2 to 1, depth of water 7 ft., and with a space from 100 to 125 ft. left between the edge of the cutting and the spoil bank on account of the extremely soft peat formation. The stability of the berms required material to be spoiled at this distance from the canal, making the average haul over 200 ft. The 1½-yd. buckets while handling peat averaged 1.77 cu. yd. per trip; 50 trips per hr. were frequently made by each bucket, and 70 per hr. was recorded for a single bucket.

From Oct. 10 to Dec. 20, 1904, which time included 60 working days, a total of 131,414 cu. yd. were excavated, the complete plant working three 8-hr. shifts per day. This output was secured at a total cost of 7.42 ct. per cubic yard, including the total cost for labor, fuel, supplies, and a proper proportion of the repairs, as well as a charge against the cableways of $9.80 per day for the general expense of office, engineering, and superintendence not directly chargeable to the cableway. The actual labor force per day of 24 hr. for the cableways amounted to $97.66, covering 6 enginemen, 6 firemen, 3 riggers, 3 pump men, 2 light tenders, 6 signal men, and a track gang comprising 15 laborers, 2 teams, and

a foreman. Six and one-half tons of coal were required per day of 24 hr. The cost of 7.42 ct. per yard also includes the lights for

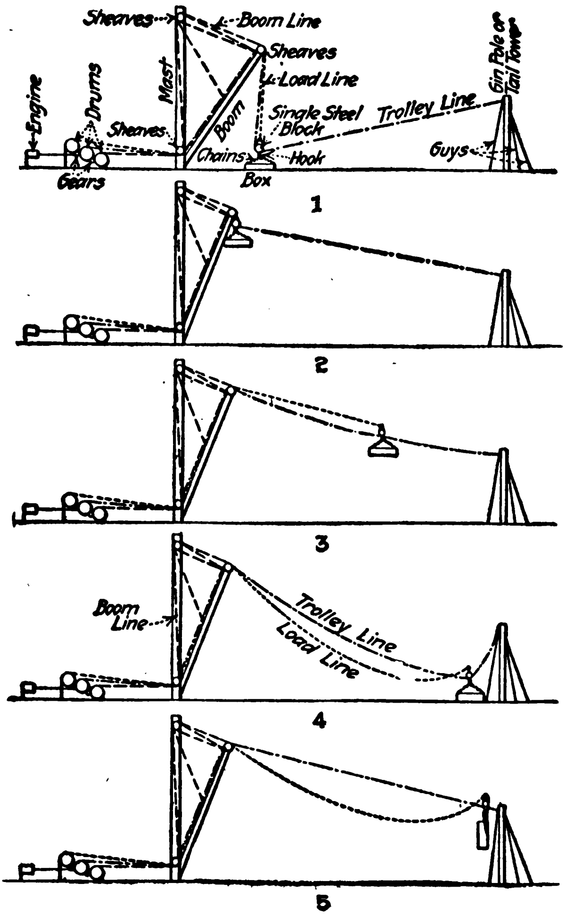


Fig. 22. Progressive Operations of Derrick-Trolley in Lifting and Transporting Skip to Dump.

night work, as well as coal, supplies, and labor for the locomotive and train service, which should not be directly charged to

cableway operation, as it was required for general service purposes, handling supplies and men.

The excavation during the above period averaged 8 to 10 ft. in depth. The banks were extremely soft, rendering the maintenance of the cableway tracks extremely expensive. In fact, no other form of excavator could have been used, the soil being too soft to sustain a steam shovel, the cableway also having the great advantage of spoiling the necessary distance away from the ex-

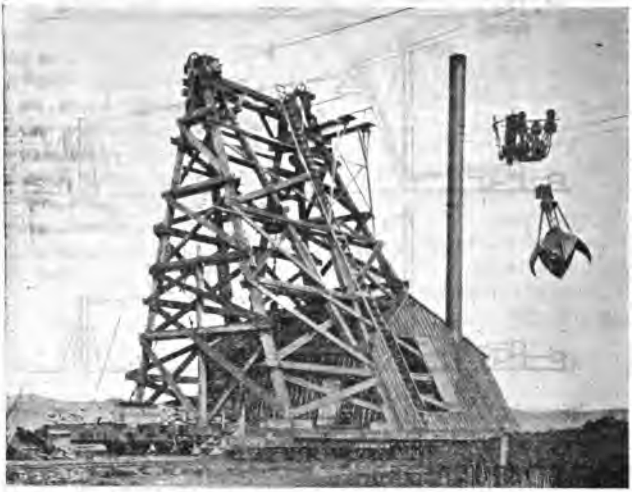


Fig. 23. Lidgerwood Duplex Travelling Tower on Hennepin Canal. Height 57 ft. Forms Head Support for One Cableway; Tail Support for the Other; Cables, 18 ft., Center to Center.

cavation. For one period of 10 days the cableway operating cost was only 5.9 ct. per yard.

Drag-Line Cableway for Dredging. According to *Engineering Record*, Feb. 17, 1915, in dredging a 200-ft. channel of the Wisconsin River at Rothschild, Wis., to a depth of 8 ft. for a distance of 1 mi., 801 cu. yd. of sand and gravel were removed in a 10-hr. day by a 2-cu. yd. Shearer & Mayer bucket, which operated on a drag-line cableway having a span of 480 ft. The average daily excavation was 500 cu. yd. The engine and boiler used in operating the bucket were mounted on a movable, self-supporting tower, 60 ft. high. The tail end of the cableway was anchored to a bridle cable, which, in turn, was anchored to clusters

of piles, driven 20 ft. into the bed of the river. In order to keep the drag-line cableway at right angles for different positions of the tower while working between two clusters of piles, the cable arrangement shown in Fig. 24 was adopted. The plant was operated day and night, light being furnished by a local power company. The maximum number of bucket trips totaled 53 per hr. For future operation the tower is being mounted on wheels instead of rollers.

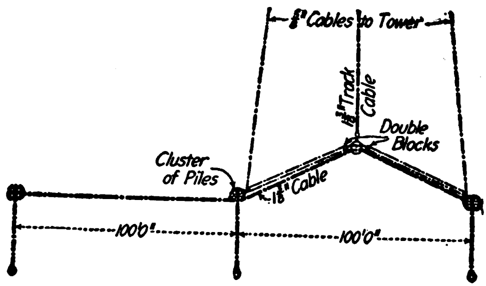


Fig. 24. Sliding Anchorage of Track Cable.

Drag-Line Cableway on Levee Work. *Engineering News*, Sept. 10, 1914, gives the following:

A cable drag-scraper was used on Mississippi Levee work during 1914. The machinery comprised a drag-scraper bucket, hung on a cable between two towers. One tower was a braced structure of considerable height located back of the levee, and the other was a single low A-frame (with counterweights for balancing the cable) located about 500 ft. riverward. The buckets picked up the earth from the marl pit between the towers and dragged it along the levee where it was dumped. The empty and full buckets sliding over the levee served to compact the fill. The outfit used at Scanlons' Landing, Memphis, Tenn., moved about 1,200 cu. yd. per day at a saving of about 30% over the team scraper method usually employed. A 4.5-cu. yd. bucket was used and deposited layers 18 to 24 in. thick. The round trip of the bucket averaged about 2 min.

Further data on the use of excavators of this type will be found in the chapter on levees.

Other Data on Cableways. In Gillette's "Rock Excavation" will be found further information on the methods and costs of handling material with cableways.

Belt Conveyors. The essential parts of a belt conveyor are:

(1) the belt that carries the material, (2) the runners upon which it travels, and (3) the driving drum. Generally the belt is of canvas, covered with rubber, thicker at the center than at the sides. Upper runners carry the loaded belt and usually consist of three wheels set so as to form the belt into a trough. Belt conveyors find their most important use as accessories to other machines, as, for example, on dredges, trench excavators, and the like.

For a more complete discussion of belt conveyor transportation see the "Handbook of Mechanical and Electrical Cost Data," by Gillette and Dana.

Capacity of Belt Conveyors. R. W. Dull, in *Engineering and Contracting*, Sept. 29, 1909, gives the following:

Diagrams 25 and 26 are based on good feeding conditions. If good feeding conditions are not obtainable, allowance must be made on the chart. This is a condition which varies so much we can not set down any rigid rule, but must leave it to the judgment of the user of the chart to make proper allowance. Variation as great as 50% is likely and certainly many where 75% of chart rating is advisable.

Material with large lumps, on an inclined conveyor, will be apt to roll back some, so the capacity allowance should be liberal, and the speed should be reduced slightly, if the conveyor is carrying material down an incline, as the motion of the belt will start the lumps rolling down. These lumps may possibly jump out of the trough of the belt.

Conveyors going up an incline and fed uniformly, can usually go up an angle whose tangent is greater than the co-efficient of friction of material on the belt, because the material forms a back stop all the way up the incline. But if the feed is intermittent, the material is apt to get started down the incline and the motion of the belt will have no influence on the motion of the material.

Conveyors should be fed so that the material is delivered in the direction of motion of the belt and with the same velocity as the belt is moving, if possible.

Life of Belt Conveyor. Assume 150 days life (6 months of 25 days). This is 1,500 hr. (working 10 hr. per day). 24-in. belt cost $6 to $9 per lin. ft. of conveyor in 1914 for belt above (capacity 125 tons per hr.). Assuming an average load of 70 tons per hr. the belt will carry 105,000 tons. Belt for 100 ft. of conveyor will cost $600–$900. Thus the cost of belting for moving material is, ⅝–1 ct. per ton per 100 ft., or 37–55 ct. per ton mile.

Excavating a Cellar with Scrapers and a Belt Conveyor. A

large cellar excavation 19 ft. deep, was dug in New York in Dec. and Jan., 1899–1900, by wheel scrapers loading onto a belt conveyor. An open trench about 7 ft. deep was excavated across the site to the river front. In this trench was a belt conveyor

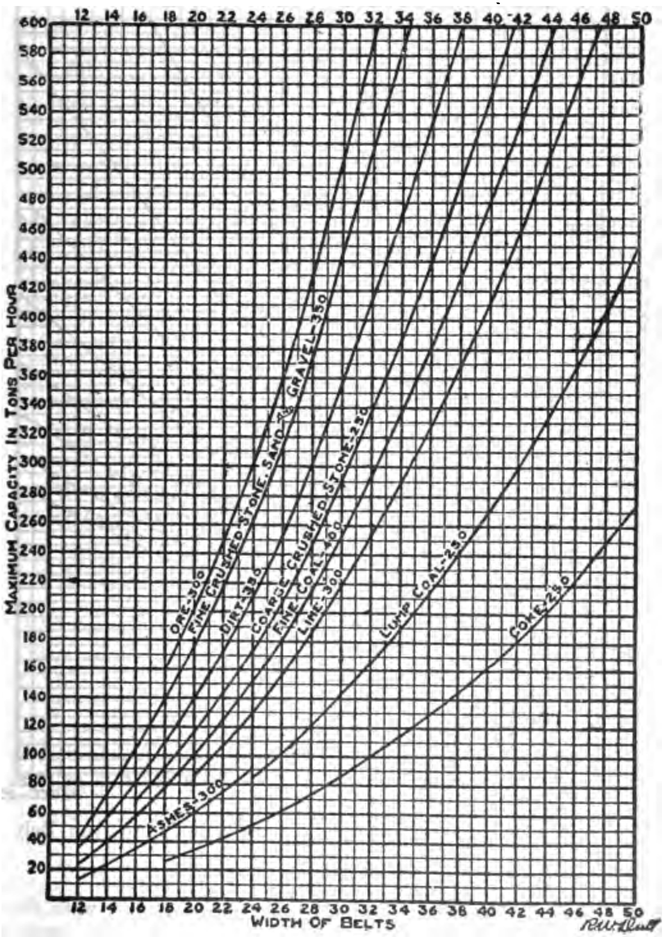


Fig. 25. Diagram for Obtaining Width of Belts. Recommended Speed Given on the Curves.

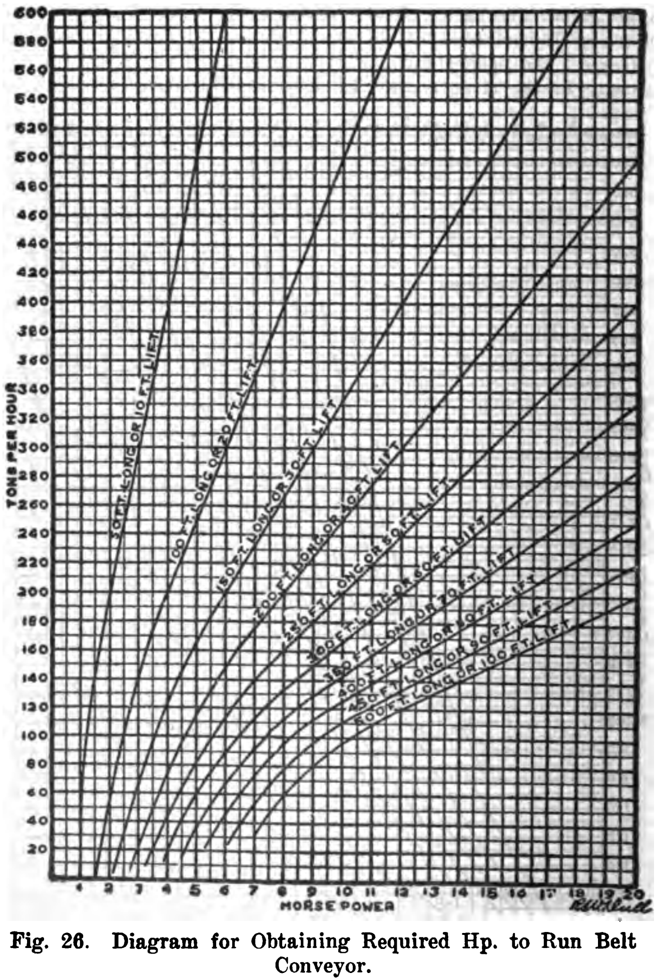


Fig. 26. Diagram for Obtaining Required Hp. to Run Belt Conveyor.

30 in. wide and about 250 ft. long. Across the trench were three bridges with 3 x 3-ft. openings or traps, and over these the scrapers were hauled and dumped. The material was lifted 20 ft. by the belt conveyor and dumped into barges. About 1,200 cu. yd. per

9.5-hr. day were thus delivered by a force of about 75 men, two 2-horse plows and twelve 2-horse wheelers.

Power was furnished by a small horizontal engine.

The material was a mixture of earth and rubbish, containing many stones weighing over 100 lb.

A Long Belt Conveyor. In 1908 a belt conveyor 2,000 ft. long was built for conveying shale from a quarry to a cement plant in the South. As described by Mr. E. C. Soper before the American Society of Mechanical Engineers it consists of a 24-in., 8-ply belt in two sections, one section being 1,000 ft. between centers and the other 1,100 ft. The belt is flat and carried by rollers, the top rollers being 4 ft. apart and the return idlers 12 ft. apart. Guide rollers about 40 ft. apart were placed on the upper and lower belts. The contraction and expansion due to the exposure to the weather are taken up by tension carriages at each belt. All loads are carried down hill and more power is required to operate the belt empty than loaded. The power is furnished by two 10-hp. engines.

TABLE I. COST OF COMPLETED BELTS INCLUDING ELECTRICAL MOTORS, TRESTLING, ETC.

	Total cost
Lumber	$ 496.34
Belt	5,361.52
Castings	1,435.77
Electrical equipment, including two 10-hp. motors..	637.11
Miscellaneous nails, bolts, screws, iron, etc.	193.20
Labor	962.20
Total 2,080 ft. at $4.37	$9,106.16

Note: Length of first section, center to center, 998 ft.; second section, 1,082 ft; total 2,080 ft.; take-up 15 ft. Cost of casting includes machine work, etc.

TABLE II. COST TO OPERATE AND MAINTAIN BELT CONVEYOR

	Per 10-hr. day	Per ton
Power:		
10 hp. at 0.4 ct. per hp.-hr.	$0.40	$0.0020
Labor:		
Boy oiling, etc., $0.75	0.75	
Taking up slack once in 7 days, 2 men, 3 hr.	0.17	
Total labor	$0.92	$0.0046
Supplies:		
Belt lacing, waste, resin, etc.	$0.20	$0.0010
Total	$1.52	$0.0076
Oil (no charge, using waste oil from large crushers.)		
Interest:		
Interest, depreciation, renewals, 10% on investment of 9,200	$2.52	$0.0126
Grand total	$4.04	$0.0202

Tables I and II give the cost of installation and of operation. The cost per unit of operation is based upon a capacity of 200 tons conveyed in 10 hr. Doubling the output (which seems practical) will reduce the operating cost to 1 ct. per ton.

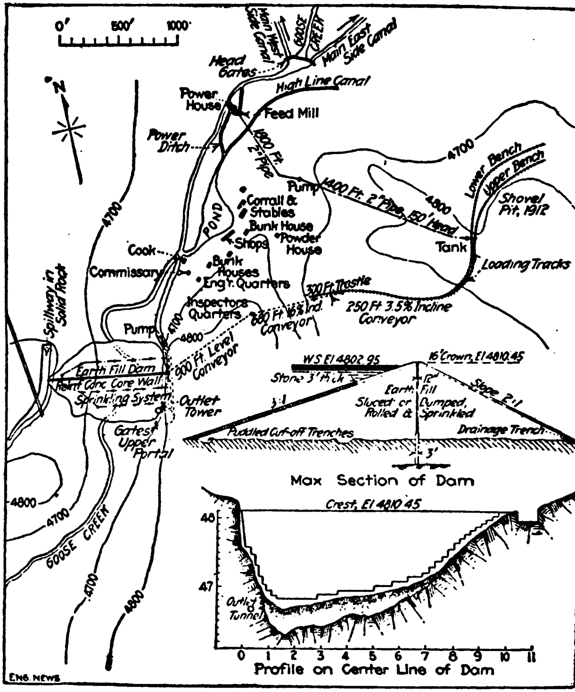


Fig. 27. Plan and Profile of Goose Creek Dam, Showing Location of Conveyors.

Conveying and Spreading at the Twin Falls-Oakley Project. This work is described in *Engineering News*, March 13, 1913, as follows:

Conveyors. The land adjacent to the dam site is very rough, having many deep gulches. To have moved the material composing the dam by rail would have required miles of contour track laying. The location of a suitable borrow pit, as regards elevation, would have meant impossible grades for dinkey trains

if bridges were built across the gulches. This led to the adoption of the conveyor system, as shown in the general plan, Fig. 27. The three units are (A) a level conveyor 920 ft. long; (B) a 680-ft. conveyor on a 16% grade; (C) a 250-ft. conveyor on a 3.5% grade. These conveyors are built on trestles whose maximum height (Conveyor B) is 68 ft. at Mill Gulch.

In general, the bents have two posts, are on 24-ft. centers, and the stringers are on 42-in. centers. The head drive and tail-drum frames are anchored in concrete which is set on solid rock. The belts are of rubber, 36 in. wide and six-ply.

When the dirt becomes wet in rainy weather it is very hard to handle it in the chutes at the dam. To avoid this difficulty as much as possible, and as a protection for the belts against the sun and wind, the conveyors were housed.

To take up the slack in the belts, which in the case of long belts is an important consideration, two types of idlers were used, one of the gravity type, the other of the "S" type. Both were efficient, but the latter has an advantage where there is little underneath clearance. The belts are run on a speed of 450 ft. per min. and easily handled 750 4-yd. cars in a 10-hr. shift. This amount could have been increased 25% by speeding up the belts and loading heavier. The maximum output for both shifts was made in September, 1912, when 105,000 cu. yd., measured in place, were conveyed. The average output for the season was about 95,000 cu. yd. per month. The night shift handles about 90% of what the day shift does.

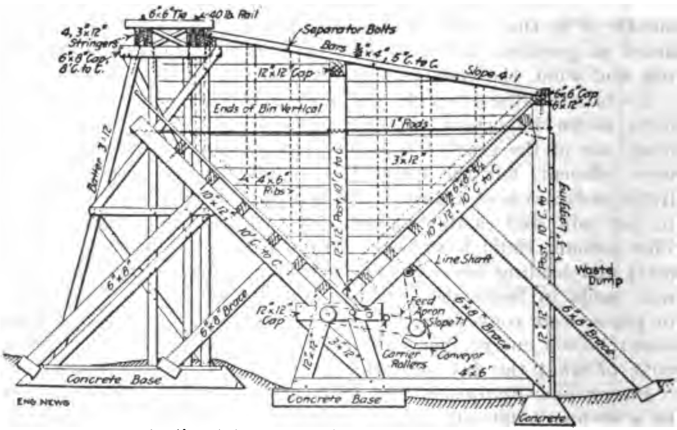
Power and Equipment for Conveyors. Conveyor A is driven by a 40-hp., 2,200-volt, 60-cycle, 3-phase, type F.H., Westinghouse induction motor; Conveyor B, by a 75-hp. motor of the same type as the Conveyor A machine, and Conveyor C by a 30-hp. motor, also the same type as the Conveyor A machine. Running under no load the conveyor system requires about 50 kw., and when under full load from 100 to 125 kw. The variation is caused chiefly by the run-of-pit material, which at times has a great deal of gravel in it, and again may be all earth. The motors are started in succession, beginning with Conveyor A, a signal system being used by the motormen to communicate with each other. In this way the starting torque does not exceed 150 kw. or 200 hp.

Current is brought from a hydro-electric plant on the Snake River, a 3¾-mile private transmission line being built from Oakley to the dam by the Construction Co.

Feed Hopper. A feed hopper of 300 cu. yd. capacity is built over the end of Conveyor C (see Fig. 28). It has three compartments, with individual openings, so that different kinds of

pit material may be kept separated and conveyed to the dam as needed. The coarser material is used on the downstream side and the more select in the trenches and on the upper toe. A trestle alongside the hopper carries the dirt trains out on it so that they can dump into the hopper.

A grid of parallel bars, 5 in. c. to c., with a slope of 4 to 1 down from the track, covers the hopper. The bars are ¾ x 4 in. in section and 24 ft. long. This grid separates all large rock and lumps of cemented gravel which cannot be broken up, and they are wasted on a near-by dump. As many as 18 men have been used



Sectional Elevation of Loading Hopper

Fig. 28. Details of Loading Hopper.

here when the large cemented lumps came, but ordinarily two or three men could keep the bars clear.

The openings under the hopper are 1 ft. by 4 ft. wide, with no doors. Feed belts, 8 ft. wide of 30-oz. canvas, revolving under these openings, catch the material and drop it onto the conveyor belt. These three belts, which are independent of each other, are operated by chain drives and friction clutches from a line shaft which extends to the tail drum of Conveyor C.

Storage Bin. On the east cliff, under the head drive of Conveyor A, and on the center line of the dam, a storage bin is built with two chutes leading from it. This bin has a capacity of 200 yd. and was designed to provide for the fluctuation in the conveyor haul. The two chutes are built on trestles with a slope of 47.5° and have a section of 20 x 22 in. They are covered

with doors and lined on the bottom; one with crescent-shaped iron castings and the other with 4-in. cottonwood blocks, set on end. Both chutes were satisfactory except that when the material got wet it would cake against the sides and bottom and the entire section of the chutes would gradually choke up. At such times it required from two to six men to clean out one chute while the other was being used. Because of this caking, which continued to a certain extent throughout the entire season, it was found that neither the iron nor cottonwood block linings wore down to any appreciable extent.

A portable hopper, with a capacity of eight wagon loads, was placed under the lower end of the chutes, which are parallel and 5 ft. apart. The dump wagons come under the hopper and are loaded. When running steadily four 1.5-yd. dump wagons are loaded per min., one man operating the feed door of the hopper. Another man operates the chute gates, which are up under the storage bin, keeping the portable hopper full. At first the gates were placed at the lower end of the chutes and wagons loaded directly from them, but this proved very unsatisfactory, as the material would pack and choke in the chutes when the gates were closed. The material would not run smoothly, but moved in sections, one section making a heavy impact against the section below when it suddenly became released and slid down. As the fill of the dam rises, the chutes are cut off and the loading hopper raised.

Belt Conveyor on the Lahontan Dam. In the construction of the Lahontan Dam on the Truckee-Carson Irrigation Project, Nevada, a Stephens-Adamson belt conveyor was used for placing the entire quantity of embankment material, amounting to about 700,000 cu. yd. The construction of the dam is described by D. W. Cole, Project Manager of the U. S. Reclamation Service, in *Engineering News*, Apr. 22, 1915.

The embankment itself was composed of two portions; the upstream portion was a prepared mixture of gravel and a volcanic ash or silt in nearly equal parts, wetted and rolled and thus forming a fair cement. This mixture was found by careful and repeated experiments to approach the greatest density and water tightness. The downstream portion of the embankment was built of "pit-run" gravel to afford a ready escape to the water percolating through the upstream "water-tight" section. The belt conveyor system had a peculiar advantage not only in reducing the cost of delivery, but in securing a perfect blending of the embankment material.

The power for the work was supplied by a branch of the Truckee River, diverted into a canal of the main channel at Reno,

Nevada, 60 miles away. The canal is used for irrigation purposes and empties into the Carson River at Lahontan, a point below the dam site. Here there was sufficient drop of water in passing through a large penstock to operate two 1,600-hp. turbine wheels. These wheels were direct connected to generators and furnished all the power required.

In a letter to the author Mr. Cole gives the following data relative to the earth handling plant: "The borrow pit was situated from ¼ to ½ mile from the dam. Material was loaded onto 4-yd. dump cars by electric excavators. Seven-car trains were hauled by 14-ton Porter locomotives over 36-in. gage endless track, the cars being dumped into bins of about 500 cu. yd. capacity. Under these bins a 36-in. by 110-in. belt conveyor was loaded by automatic feeders for delivering measured quantities of "silt" and "gravel" for composing the impermeable embankment mixture. The 36-in. belt delivered these materials onto the 30-in. conveyor extending 925 ft. from the storage bins to about the middle of the embankment. The total quantity of material handled in this manner was 612,000 cu. yd.

The cost of this conveyor system "A" was as follows:

Conveyor "A"—	
30 in. x 925 in. conveyor	$ 8,022.00
36 in. x 110 in. conveyor	1,497.00
Automatic feeders	1,243.00
	$10,762.00
Freight	1,281.73
Total	$12,043.73
Labor and superintendence erecting supports, bins, etc.	$ 5,067.41
Materials, lumber	3,732.12
Materials, miscellaneous	209.62
Supplies and miscellaneous	1,072.59
Labor, installing machinery, etc.	1,878.20
Overhead charges	2,369.09
Total for Conveyor "A"	$26,372.76

Results of operation were as follows:

Operation of Conveyor "A"	Total	Cost per cu. yd. of earth
Labor — conveyor operation	$ 9,857.27	$0.016
Supplies — miscellaneous	718.96	0.001
Power plant operation	3,200.54	0.005
Repair plant operation	1,269.87	0.002
Depreciation	23,062.88	0.038
Total	$38,109.52	$0.062

The main conveyor was driven by 100-hp. motor installed midway of its length.

The feeders and cross conveyor were driven by a 20-hp. motor.

Electric current was generated at the site of the work by utilizing the drop of the main canal, and the total cost of production was about 1 ct. per kilowatt hour.

Common labor was paid 30 ct. per hr. and mechanics ranged from $3 to $5 per day. Work was carried on in one 8-hr. shift daily extending over two years with intermissions of a few weeks during the coldest weather.

The conclusion is that the work was done at least as cheaply and probably at less cost than with the borrow pit tracks extending out over the dam on high trestles. Certainly the regularity and uniformity of distributing the material together with the perfection of mixing the materials in the desired proportions were far better achieved than would have been possible by dumping cars from any considerable elevation. The reliability and freedom from all mishaps with the belt conveyor were most satisfactory. The capacity was abundant and the output was limited only by the ability of the borrow pit crew to feed the belt at one end and the ability of the distribution force to place the material in the dam at the other end. Sometimes one and sometimes the other of these considerations governed the rate of progress which was never limited by the conveyor.

A Bucket Elevator Plant. *Engineering and Contracting*, June 10, 1908, gives the following:

The bucket elevator was 110 ft. long between centers, and had a 5-ft. "lap-over" at the top so as to discharge the material into the center of a bin.

The elevator was operated at a speed of 250 ft. per min., with buckets spaced 20 in. apart. The material was discharged from dump cars into a "boot" at the foot of the elevator. Each bucket had a capacity of 15 lb., and, at the rate of 150 buckets per min., the capacity was 60 cu. yd. per hr.

The speed of 250 ft. per min. was noteworthy, and was due to the special design of the link chain.

This particular plant was one installed for removing the excavated material from the North River Tunnel, built by the Hudson River Railroad Co. The installation is one of several made for the same company by the Link Chain Belt Co. of New York City.

Bucket Conveyor for Backfilling Retaining Wall. W. F. Schaphorst in *Engineering and Contracting*, Aug. 16, 1916, gives the following:

A large river wall was very recently completed in Cedar Rapids, Iowa. This wall was of concrete and was 26 ft. high and designed to protect abutting property from the seasonal floods of the Red Cedar River. When the footings were built the mud excavated from the site was piled in front, forming an earth cofferdam.

After the wall had been completed this same mud was used as backfill.

The problem of moving the mud from in front of the wall to its desired position behind it was solved by the construction of a novel and effective ladder conveyor. The buckets of this conveyor were wide strips of metal which slid up a plank at an angle of about 60° with the plank and emptied as they passed over the sprocket at the top. A gang of men at the bottom shoveled the mud into the buckets.

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CHAPTER XIV

METHODS AND COST WITH DRAGLINE SCRAPERS

Dragline or Power Scrapers. These are scraper buckets pulled by a cable. If the scraper is bottomless it is not raised from the ground when loaded. Dragline scraper buckets having bottoms are so rigged that they can be hoisted after they are filled.

Bottomless Power Scrapers. These range in size from ½ to 7 cu. yd. capacity. The sizes, weights, and prices of the Sauerman power scraper are given in Table I.

TABLE I. SAUERMAN POWER SCRAPER

Capacities cu. yd.	Dimensions ft.	Weights lb.	Approximate prices prior to 1916
½	3.25 x 3.5 x 1.3	1,600	$250
¾	4.5 x 3.5 x 1.5	1,900	300
1	4.5 x 3.5 x 2	2,300	350
1½	5.5 x 4 x 2.3	3,000	425
2	5.5 x 4.5 x 2.3	3,500	600

These machines consist of two heavy side plates and a back plate, with a renewable cutter edge fastened on a runner frame pivotally and adjustably connected to the back plate. When the scraper is pulled forward the runner frame and cutter edge are tilted to the digging position. When the empty scraper is pulled back this runner edge and cutter frame is pulled flat, thus forming a sled for the scraper. The load is not dumped but is left at the point where the scraper starts back. This is a desirable feature in sticky material. These machines require a 35 to 80-hp. engine, ⅞ to 1-in. haul back lines and 1 to 1¼-in. pull lines.

Early Power Scrapers. First on the Chicago Canal and later on the Massena Canal (*Engineering News*, Aug. 15, 1895, and Dec. 15, 1898), a power drag scraper was used. The scraper held 3 cu. yd. of loose earth when not heaped and had a cutting edge 7 ft. wide.

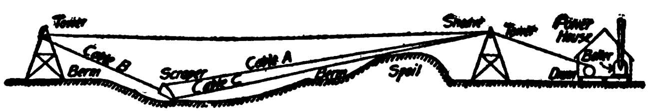


Fig. 1. Power Scraper on the Chicago Drainage Canal.

It was operated by cables (Fig. 1) running to a 12¼ x 15-in. engine. The towers at Massena were mounted on trucks and were 720 ft. apart. Cable A was used to dump the scraper. The scraper worked there in soft clay, cutting a deep swath; then it was moved over to cut another swath leaving a ridge of earth between the two for the purpose of guiding the scraper. Its

output in this soft clay was said to be 800 cu. yd. per 10-hr. day, but the actual records on the Chicago Canal showed only 250 cu. yd. daily output. Mr. Charles Vivian was the designer and contractor in both cases. The scraper did not work satisfactorily in hard material, nor in very wet material, nor in frozen material.

On the Erie Canal deepening (1897) small power operated scrapers were used on one contract to drag muck and earth over to a steam shovel which loaded it into cars. The engine was mounted on trucks. A horizontal wooden boom 50 ft. long, with a sheave for the tail rope at the end of the boom, was fastened to the engine truck platform. One or two men attended to

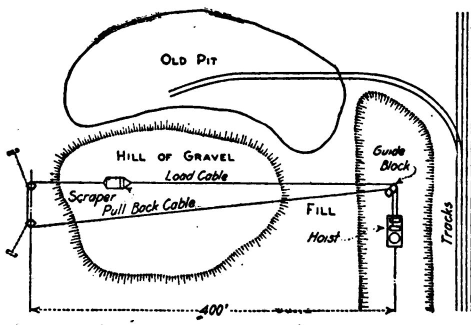


Fig. 2. Layout of Plant for Stripping Overburden with Bottomless Bucket.

loading and dumping the drag scraper which they could readily do as it was small. The hoisting engine thus merely pulled the scraper back and forth.

On the Suwanee Canal (*Engineering News*, Feb. 20, 1896), a power-driven bucket-scraper was used, the Trenton Iron Co., Trenton, N. J., being the manufacturers. Instead of towers, two masts provided with guy lines were used. After the bucket-scraper was loaded by a cable from the engine, another cable lifted it, and it traveled on a trolley conveyor to the dump, very much as buckets travel in the Carson-Lidgerwood cable trench machine. It is said that 200 cu. yd. of earth were moved daily for 6 ct. per cu. yd. with this device.

Overburden Stripping with Bottomless Bucket. At the plant of the Diamond Sand and Gravel Co. at Bedford, O., a 1-cu. yd. Sauerman bottomless scraper, operated by a 60-hp. electric hoist, was used to remove the overburden from a deposit of gravel, the

material removed being deposited in a ravine on one side of the gravel deposit. The hoist is a type specially designed for scraper work, the rear drum operating the "pull-back" cable having a speed three times as great as the front drum. The machine requires one operator and a rigger stationed at the guide blocks to make the necessary shifts in the line of operation. This outfit installed represents an investment of about $5,000.

The top soil of the hill is largely clay and runs from nothing to 6 ft. in depth. Hard "shoulders" of clay, when encountered, are removed by "sawing" the scraper back and forth over the obstruction. A day's output will fluctuate between 200 and 300 yd., depending on the nature of the material.

Cost with a Bagley Scraper on Road Construction. In *Engineering News,* Dec. 17, 1914, F. W. Harris gives data on the use of the Bagley power scraper on mountain road construction. He states that it is a most successful machine when used in connection with a logging donkey engine. The right of way is first cleared of logs, etc., by the donkey engine operating a cable. The scraper is then attached to the same line. With plenty of fuel and water and a short haul not exceeding 400 ft., a scraper should remove at least 400 cu. yd. of earth per day. In light earth and gravel cuts with a 200-ft. haul a 2.5-cu. yd. scraper will push another 0.5 cu. yd. of material ahead, and should easily move 1,000 cu. yd. in 10 hr. These scrapers are unsuccessful, however, in mucking out blasted rock. They will handle all kinds of loose earth, gravel, and boulders from 1 cu. ft. to 0.5 cu. yd., but the material must be loose. Wherever the fill is of considerable quantity, the haul short, and the material sandy or gravel, scraper work should cost about 7 ct. per cu. yd. On general road work, where time is lost in moving up, splicing lines, removing large boulders, etc., the average cost will run from 15 to 20 ct. per cu. yd., to which must be added from 3 to 5 ct. per cu. yd. for finishing as the scraper leaves the work in a rough shape.

On certain work two scrapers were in use, each having a capacity of 2.5 cu. yd. One donkey engine was 11 by 13 in. in size, and the other 10¼ by 10½ in. The wire cables had the following dimensions: main line 1⅜ in. and haul-back line ⅞ in.

The 10-hr. daily cost of a road gang was as follows:

Foreman	$ 6.00
Engineman	3.50
Fireman	2.75
Hook tender	4.50
Pumpman	3.00
Two rigging men @ $3	6.00
Total labor on scraper	**$25.75**

One team hauling fuel or two men cutting on right of way...	$ 6.00
Fuel	10.00
Use of donkey engine including depreciation, cable costs, etc.	10.00
Two teams and teamsters for finishing @ $6	12.00
Four laborers, finishing @ $2.50	10.00
Total daily cost	$73.75

Assuming 400 cu. yd. for an average day's work, the cost will be $0.185 per cu. yd.

A Power Scraper for Handling Mud. *Engineering and Contracting*, Sept. 11, 1910, gives the following: In excavating the Long Island open cut and tunnel approaches to the new Pennsylvania R. R. East River tunnels a considerable portion of the overlying swamp mud unsuitable for embankment was wasted over an adjacent area of swamp land. As this swamp area was

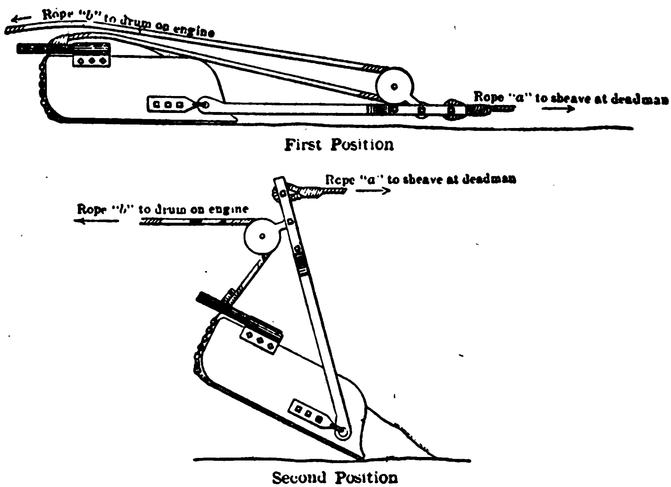


Fig. 3. Rigging for Scraper Bucket.

of such a character that spoil car tracks could not be laid or maintained on it, use was made of drag line scrapers to distribute the spoil. On one side of the swamp area two travelers were mounted so as to run back and forth along the edge of the swamp. A double drum hoisting engine mounted on each traveler operated a scraper rigged as in Fig. 3. Referring to the drawing, the scraper was pulled forward by the rope *a* which passed through a sheave attached to a deadman on the opposite side of the swamp from the traveler, while the rope *b* was allowed

to run loose as shown by the upper sketch of the drawing until it was desired to dump the scraper. This was accomplished by clamping the lower drum operating rope *a*, and pulling the rope *b* until the scraper was in the position shown in the lower portion of the drawing when a slight pull on the rope *a* with rope *b* slacked a corresponding amount completed the turn. The scraper was pulled back to the starting point by the rope *b*.

A Bottomless Scraper for Loose Material. *Engineering and Contracting*, May 15, 1912, gives the following: Fig. 4 is a type much used in the Joplin, Missouri, mining district for loading mine tailings into cars. It should prove useful for handling

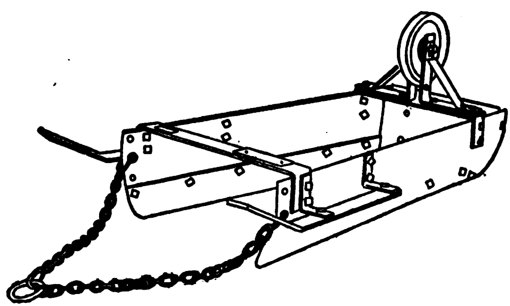


Fig. 4. Bottomless Drag Scraper for Loose Materials.

loose material of other kinds. This scraper has no bottom and thus handles the material by pushing it ahead of it. It is operated by means of tail and head ropes from a two drum engine. The scraper illustrated is 5 ft. 2 in. long 3½ ft. wide in front and 4 in. wider at the rear, and is 14 in. deep.

A Power Scraper and Wagon Loader. *Engineering and Contracting*, Dec. 9, 1914, gives the following: The machine consists of an inclined runway mounted on a truck, together with a drag scraper. The scraper is hauled back into the excavation 100 to 500 ft. for its load, which it carries up the runway of the incline and dumps automatically into a hopper at the top to be loaded into wagons. The scraper is dragged by a continuous drag line running over a pulley at the top of the machine and another pulley anchored at any convenient point in the excavation. Power is supplied by a gasoline engine, or an electric motor. The hopper from which the wagons are loaded has a capacity of 1½ cu. yd. and the gate, placed 6 ft. above the ground, may be operated by the engineman. A 125-gal. water tank is mounted

on the truck. The front wheels under the machine are in pairs, permitting easy rotation of the apparatus to load from any position of the excavation.

The outfit is manufactured in three sizes of 6, 10 and 20 cu. ft. scraper capacity and has a rated output at 100-ft. haul of 15, 25 and 40 cu. yd. per hr. for each size, respectively. The maximum heights vary from 14 ft. to 16 ft.; length from 20 ft. to 22 ft.; widths from 5½ ft. to 8 ft.; and shipping weights from 7,000 lb. to 12,100 lb. Engines vary from 10 to 25 hp. Scraper speed may be varied from 150 to 350 ft. per min. Under ordinary conditions a cost of 4 ct. per cu. yd. for excavating and loading is claimed for their machines.

The apparatus is manufactured and sold by the Insley Mfg. Co., Indianapolis, Ind.

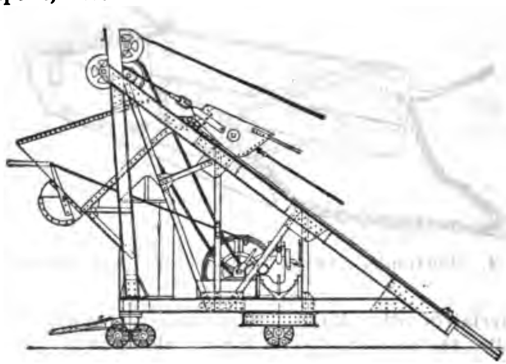


Fig. 5. Power Scraper and Wagon Loader.

Portable Derrick Excavator. *Engineering and Contracting,* Oct. 14, 1914, gives the following: This excavator (Fig. 6) will handle a ½-cu. yd. bucket on a 20 to 22-ft. boom with a range of hoist up to 12 ft. Except the boom, which is wood, the construction is steel and steel outriggers are provided. Where conditions do not permit the use of outriggers, guy ropes can be substituted. The machine is transported by team and pole, neckyoke and single and double trees are provided. The engine is vertical, double cylinder and geared giving a rope pull of 4,200 lb. at a speed of 100 ft. per min. All other parts including wire rope, blocks and fittings are the manufacturers' standard except the digging bucket which may be any make preferred by the purchaser. The machine has a digging capacity of 20 cu. yd. per hr. and in actual work has shown much higher records. The

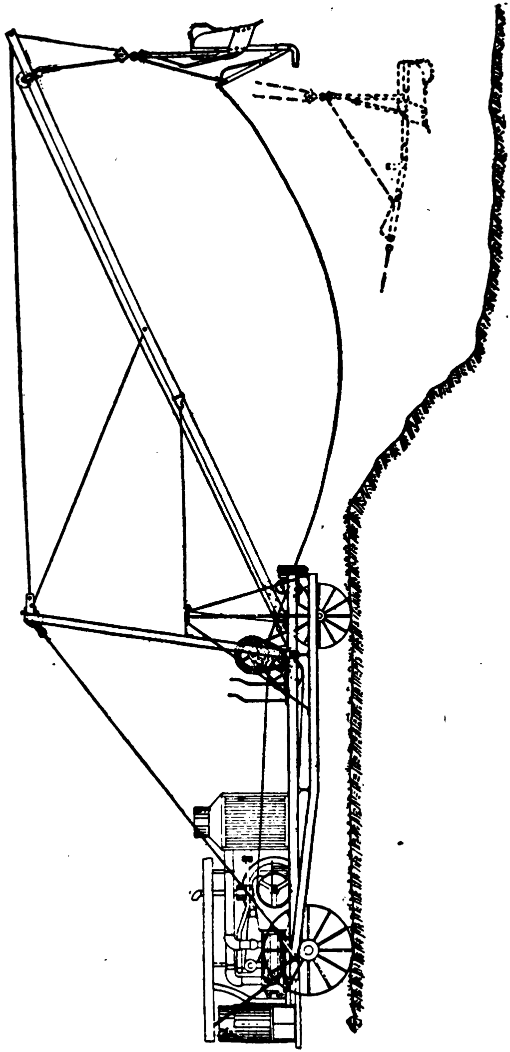


Fig. 6. Portable Derrick Excavator.

cost of the machine is under $2,000. It is made by the John F. Byers Machine Co., of Ravenna, Ohio.

A similar machine made by the Economy Excavator Co., Iowa Falls, Iowa, is shown in Fig. 6.

Cableway Scraper for Sidehill Work. *Engineering and Contracting*, Oct. 9, 1907, gives the following: The arrangement illustrated in Fig. 7 was used in removing part of a hill face that caused a skew pressure on a tunnel being constructed through a hillside. As shown, the device consisted of a timber tower, about 50 ft. high, to which was attached a suspension cable of 1½-in. wire rope, secured at the uphill end to a movable holdfast, which allowed swinging the cable laterally with the

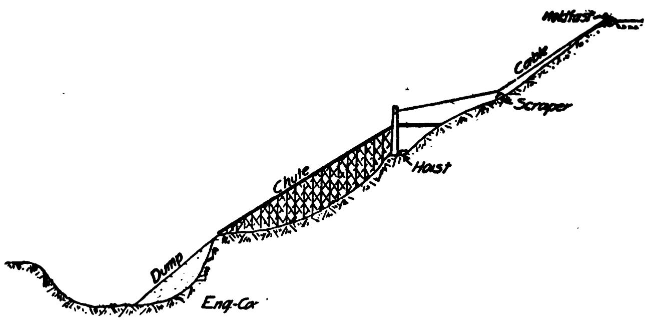


Fig. 7. Cableway Scraper for Sidehill Work.

tower as the center. A boiler plate scraper pan, 6 ft. wide, was suspended from a traveling block on the cable. Up and down haul lines were attached to the scraper by a bridle arrangement, and led to the drums of a hoisting engine placed at the foot of the tower. The suspension cable was also led to one drum of the hoist by suitable blocks. This allowed the cable with traveling block and scraper to be raised or lowered by winding on or off the drum; and consequently the feed of the scraper was under control as it descended the hill.

The material was a gravel face, the work being done during the winter months, with temperature far below zero, and the hill face deeply frozen. Before the scraping was begun a V-shaped gulley for the scraper to run in was made by blasting out stumps and frozen earth, after which the sides were picked down to furnish loose material to the scraper. At the tower the scraper emptied into a plank chute 6 ft. wide, with sides 1 ft. high. The chute was placed at an inclination 1⅛ to 1, which was enough,

except when the gravel was wet from snow or rain, and then the fine sand clogged and had to be removed with pick and shovel. When the earth piled up at the mouth of the chute, a new chute higher up or slightly to one side, was constructed. Beside filling itself, the scraper would often push down a large mass of gravel, thus sometimes carrying down from 4 to 6 cu. yd. per trip. The gravel wore out the bottom planking of the chute, two sets of 3-in. plank being used up. About 30,000 cu. yd. were excavated at a cost of 30 ct. per cu. yd., this cost including running hoist, rigging scraper and material and labor in building the chute.

Leveling Ground with Power Scraper. James C. Bennett, in *Engineering and Contracting*, Dec. 4, 1912, gives the following: Gold dredging has in years past left considerable areas of ground within the city limits of Oroville, Cal., in an unsightly condition. More recently the city has demanded in new work that the dredges restore the "worked" ground to a surface approximating the original. At the outset of the work of restoration, attempts were made to use horse-drawn scrapers. Owing to the character of the material, however, the costs proved prohibitive, and a more economical method was sought. The "boats," as they are called locally, deposit the gravel, sand, and clay in irregular piles varying in height from 8 or 10 to 25 and 30 ft. above the original surface level. The deposited gravel contains rocks ranging in size from sand to 20 or 24 in. in diameter, and in some places, a considerable quantity of clay and sand. This makes a material that is very difficult to handle economically, as it is hard to fill a scraper to anything like its capacity. In using horses, the work was found to be very severe on the stock, and a team was rendered unfit for service after a very short time.

The equipment that is described was developed by one of the dredging companies, and has been used in leveling an extensive area. Until a short time ago, however, it was never used where there was any necessity for working to grade, so that little or nothing was known of the cost per cu. yd. of material handled. Consequently, when the writer attempted recently to learn what should be a reasonable price at which to contract for a job of making a fill for a street grade, filling a large water hole to a grade above that of standing water, and raising a part of the ground to a grade suitable for building lots, the only data that could be obtained were some records of costs per acre—ranging from $175 to $200. As has been pointed out, these gave no consideration to the yardage involved, so that the information was of little value.

Finally, the contractors and the writer agreed on a lump sum

for the job, based on an estimate of the time required to do the work. Sufficient record of previous work was available to afford reliable information as to the daily expense of such work, so that such an estimate was mutually looked upon as the most satisfactory. The estimated time for the completion of the job was 75 days, which should cover repairs, setting deadmen, moving lines and blocks, and moving the machine from one position to another. The elapsed time between start and finish of the work was 82 working days. Of this, 62 days were occupied in actual scraping, 10 days in moving lines and winch, and making repairs, and there were 10 working days in which no work was done for reasons not attributable to the work in question. The time devoted to actual scraping during the 62 days averaged 7 hr. per day.

Close record was kept of the number of loads hauled, and, at intervals, the loads were measured. It is believed that 1¼ cu. yd. is very nearly a correct average load. The total number of yards moved, based on the number of trips hauled, was 15,300. The regular crew consisted of a winchman and two helpers. Had this work been done in conjunction with some other, it would have been unnecessary to retain both helpers continuously on the job, since but one is needed during the time that the scraping is in progress. His work is to watch at close range and direct, by signal, the loading of the scraper. The second helper is required principally in moving blocks and lines from one deadman to another.

A little study of the job prior to starting the work of scraping materially lessened the lost time, since nearly all of the deadmen were set before the filling was begun. Thus it was only necessary to stop the work for such length of time as was required actually to move the lines from one block anchorage to another. During the execution of the work the winch itself was moved twice, that is, it occupied three positions including the one in which work was started. Throughout the greater part of the work the hauling line was run through one block only, while the back line ran through three most of the time. The costs of the job were as follows:

1 winchman	$ 5.00
2 helpers, at $2.50	5.00
1 horse (for moving lines, etc.)	1.00
133.33 kw. hr., at 2¼ ct.	3.00
Total per day	$ 14.00
Total Cost:	
72 days, at $14	$1,008.00
Repairs (materials only, labor being included above)	35.00

4-horse team, man and scraper, resurfacing street grade, 1 day	10.00
600 ft. second hand, 1¼-in. hauling line	54.00
600 ft. second hand, ⅞-in. back line	30.00
Depreciation at 10%	120.00
Total cost for the job	$1,257.00

From the foregoing figures it will be seen that the unit cost for the job was 8.2 ct. per cu. yd.

In the above statement of costs there are one or two items that involve a slightly heavier charge against the job than is strictly just. The depreciation charge is probably a little high, since, aside from the scraper itself, there is not a particularly heavy wear and tear on the equipment. The full cost of the ropes is included, although the same ropes would probably have served for the handling of an additional 2,000 or 3,000 cu. yd. of material. The second-hand ropes were secured from mines where they had been discarded as hoisting ropes in compliance with state mining laws which limit the service of such ropes to a comparatively short time owing to the extent to which human life is dependent upon its reliability. At the conclusion of the work the following figures were derived:

Average length of haul, ft.	175
Average day's duty, cu. yd.	247
Average hourly duty, cu. yd.	35.2
Largest day's duty, cu. yd.	425

A 50-hp. constant speed motor was belted to the first of two pinion shafts, and was kept running continuously while scraping was in progress, thus reducing the time of reversing the travel to a minimum. In the preparation for the job a temporary power line of 4,000 or 5,000 volts was run to the edge of the work, where the transformers were set on the ground. From the secondary side of the transformers a 440-volt current was carried to the motor by means of an armored three-conductor cable. This cable was a piece of discarded gold dredge equipment. By this arrangement, it was possible to move the winch with its own power from one part of the work to another, and still leave the transformers undisturbed. At first thought, the charge for electric power — 2¼ ct. per kw. hr.— seems high, but in view of the erection of the temporary pole line by the power company and delivering the current to the transformers at whatever point on the work the contractors selected, it will be found a very reasonable charge.

The speeds of both hauling and back lines were approximately 130 ft. per min. This proved a very satisfactory speed for the hauling line, though in other material a rate of 150 ft. could

undoubtedly be used to excellent advantage. For the back line the speed of 130 ft. was slow, and should have been increased to not less than 150 ft. per min., while it is quite possible that 175 ft. would have given good results.

The scraper, 12 ft. long over all, was built of good, sound, 2-in. planks, secured to steel end plates, and the whole thoroughly strapped with ½ x 3-in. bar steel. A bail iron was attached to each end plate, and carried on around the back as a reinforcement. At the outset some experimenting was required before the bail irons were set at the angle that gave the best results in filling the scraper. During the progress of the work, the angle

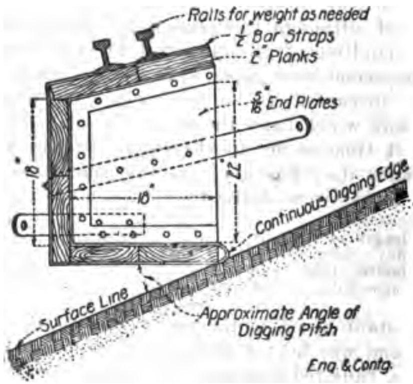


Fig. 8. Wooden Scraper for Leveling Ground.

was changed once or twice owing to varying conditions of ground and material. The back line was attached by means of short bail irons projecting to the rear of the scraper. Here again some experimenting was necessary before the irons were set at the angle that would unload the scraper to the best advantage. During the greater part of the work it was only necessary to reverse the rope travel with a light jerk to discharge the load, as the rear bail irons were so set that the scraper was tipped fairly well forward so that it was easily withdrawn from under the load. On some of the work, however, there was so much wet and very sticky clay that quite a hard jerk was necessary to clear the scraper of its load. In this the operator soon became so skilled that very little time was lost on this account.

Canal Work with a Power Scraper. This device was designed by James R. Hall, for work on the Swanee Canal, Ga., and is

described in *Engineering News*, Feb. 20, 1896. It consisted of two guyed masts, supporting a 1⅛-in. carrier cable of 200 ft. span, on which a 2-wheeled carriage traveled. Power was supplied by a double-cylinder, three-drum hoisting engine. The scraper is a rectangular bucket with the lips fitted with cutting edges. The haul or load rope led directly from the bucket-bail through a sheave at the top of the head mast to a drum on the engine. The hoisting rope led from the bail of the bucket through a sheave on the cableway carriage to a second drum. This rope was also used to pull the carriage and bucket, back from the spoil bank. A third rope, the out-haul or pull-back rope, led from the bottom of the bucket through a sheave on the cable carriage, thence through a sheave on the tail mast, and back to the engine.

The crew required consisted of an engineman, a fireman, a helper, and one signal and general utility man, besides two men who prepared anchorages, set masts, etc. The daily operating cost, including fuel and oil, was $12. The output was 250 to 300 cu. yd. per hr. day. The total unit operating cost was about 6 ct. Shifting required 1 to 1½ hr., and out of 11 hr., 3 were consumed in moving, oiling, repairing, etc.

Loading Wheelscrapers with an Engine. In *Engineering News*, June 23, 1904, G. H. Dunlop described the method used in excavating a canal in Australia. The cutting was in clay, and was 40 ft. wide, 42 ft. deep, with side slopes of 1 to 1. The material was excavated by wheelscrapers, holding 16 cu. ft., drawn by two horses. Instead of using a snatch team, an engine was placed on the bank and, by means of a ⅝-in. cable, assisted in loading. This rope was attached and detached from the scraper poles by a laborer. A pony ridden by a boy dragged the rope from place to place as required.

On another piece of work where the cut was shallow and the bottom width was 117 ft., the engine was placed in the bottom of the cut. The depth of cutting was regulated by a gage wheel under the rear end of the pole. In deep parts of the cut the pole was removed and replaced by a third wheel. The scraper was loaded by the engine, and then hauled out of the cut by a long rope attached to horses traveling on the bank.

Power Scraper Work in Oregon. C. G. Newton, in *Engineering News*, Oct. 20, 1904, gives the following: A power scraper was used to excavate gravel under several feet of water in the bed of the Grande Ronde River, Oregon. It dragged the material 200 ft. up an apron and dumped it on cars. A 30-yd. car was loaded in 16 min., and another car moved up to its place in 12 min. The cost was 7 to 8 ct. per cu. yd.

At Portland, Oregon, hard, stiff, blue clay, and a covering of 1 ft. of silt was excavated from Guild's Lake. The material was hauled from 400 to 700 ft. and dumped over a bulkhead 4.5 ft. high at the rate of 600 to 800 cu. yd. per day. The cost was 14 ct. per cu. yd.

The cost of moving dirt, sand or gravel under average conditions with a 400-ft. haul, for street grading work, was as follows per 10-hr. day:

Donkey engine	$2,250
4½ yd. Hammond scraper	500
Lines	500
Blocks	150
Miscellaneous	300
Total plant	$3,700
Interest, 8% on $3,700 ÷ 270 days	$ 0.81
Depreciation	9.20
1 engineman	3.00
1 foreman	3.50
1 fireman	2.50
1 ton coal	5.50
1 coal tender	2.50
Oil supplies	1.00
Repairs to lines, etc.	2.50
Total per day, 405 cu. yd. at 7.35 ct.	$30.51

Power Scraper Work in Alaska. *Engineering and Contracting*, Feb. 26, 1908, gives the following: In the Klondike, steam scrapers are often used in handling tailings from the creek-mining operations. The ordinary power scraper outfit used in operations on tailings consists of a scraper of from ⅓ to ½ cu. yd. capacity, operated by a double drum, 2-cylinder hoist, of 25 to 30 hp. This outfit handles on an average 250 cu. yd. of loose material in 24 hr. at an average cost of 49 ct. per cu. yd. In explanation of this high cost it may be stated that the wages of laborers are about $5 per day with board, or $8 without board; that bituminous coal at Nome costs $17 per short ton, and that spruce wood for fuel costs about $12 per cord.

The scrapers drag the material from the pit to the dump, a horizontal distance of from 100 to 300 ft., and a vertical distance of 20 to 50 ft. The gang employed usually consists of three to four men — a fireman, a hoistman and either one or two men to fill, guide and dump the scraper. The form and rigging up of the scrapers and the system of sheaves and drawback usually employed are shown in Fig. 9. Toothed scrapers are not always used, but are preferred.

An adaptation of one of these plants was used in stripping loam in excavating for a reservoir at Portland, Ore. In this case a bottomless scraper was used. The scraper had a theoretical

capacity of 6 cu. yd., but actually handled about 3 yd. In the work in seven 10-hr. days, stripping to 4 ft. in depth, 400 cu. yd. per shift were handled by the outfit. Furrows 300 ft. long were made by the scraper. A 60-hp. boiler was used but only one cord of wood, at $2, was burned per day. A double drum hoist, provided with 10 x 12-in. cylinders and geared 6 to 1, was

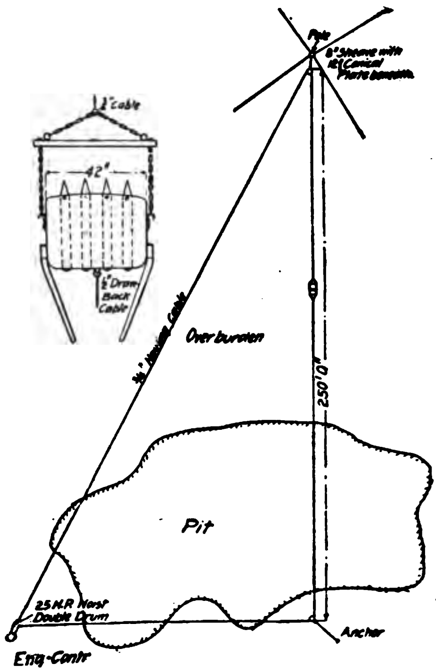


Fig. 9. Arrangement in Power Scraper Work.

used. The gang consisted of a winchman, a fireman, and two scraper men, at $2.50 per day. Under these considerations the operations were said to cost about 5 ct. per cu. yd.

Loading Scrapers by Power. *Engineering and Contracting*, Sept. 18, 1912, gives the following: In excavating for a small artificial lake for the site of a residence at Libertyville, Ill., the contractors used four-wheel Maney scrapers and loaded them by power from a stationary engine.

The lake is about 400 ft. in diameter, and the material excavated consists of a very hard brick clay. At the start snatch teams were employed to aid in loading the scrapers, but they were replaced by a 10-hp. double-drum engine. The engine is located on the bank of the lake pit (Fig. 10) and a ½-in. steel cable is run from each drum to a double sheave block about 50 ft. from the engine and through this block to any point in the pit. A small hook on the end of the cable is attached to the tongue of the scraper and pulls it along over the plowed ground until it takes its load. Another team and scraper then follows and is loaded in the same way. This continues until the end of the pit is reached. The cable is then pulled back to the far end of the pit by the last scraper loaded, while the scraper is on its way to the dump. The two cables are operated by one man at the engine, and sometimes both cables are used at one time.

The scraper consists of a scoop of 29 cu. ft. capacity, suspended on a four-wheel steel wagon frame.

A record of the work done during the month of July, 1912, is given below. The length of the haul varied from 200 ft. to as much as 1,200 ft., the average being 400 or 500 ft.

With 210 hr. of foreman time, 788 hr. common labor, and 1,794 hr. of team and driver, the output was 6,686 loads.

These data give the following units of output:

6,686 loads at 29 cu. ft. equal, cu. yd.	5,386
Average cu. yd. per team hr.	3
Average cu. yd. per scraper hr.	3.92
Average cu. yd. per scraper per day	35.3
Average cu. yd. per day	256.5

It will be noted that two teams are required for plowing on this work, and as many as four teams were used in very hard places. In the figures, however, the number of scrapers at work may be considered as two less than the number of teams.

Figuring the foreman at $3 per day, the laborers at $2.25, the driver and team at $5, the cost of the work may be estimated as follows:

	Per day
1 foreman	$ 3.00
1 dumpman	2.25
2 pitmen	4.50
1 engineman	2.75
9 teams and men and 7 scrapers	45.00
Total labor per day	$57.50
Cost of labor for 255 cu. yd. (output of 7 scrapers) per cu. yd.	$0.226

It should be remembered that the material is hauled about 500 ft. on the average and that it was very hard to dig. When

the top soil was removed, the contractor estimated that the cost was only about 10 ct. In the top soil work the digging was very easy and the haul was short.

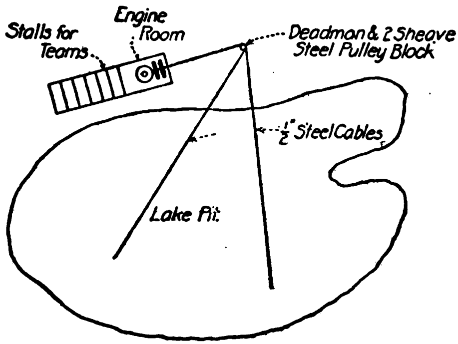


Fig. 10. Sketch Showing Manner of Loading Scrapers Using Hoisting Engine and Cable.

Basement Excavation by Power Scraper. *Engineering Record* Aug. 8, 1914, gives the following: Excavating the basement for the new office building of the Occidental Realty Company, in

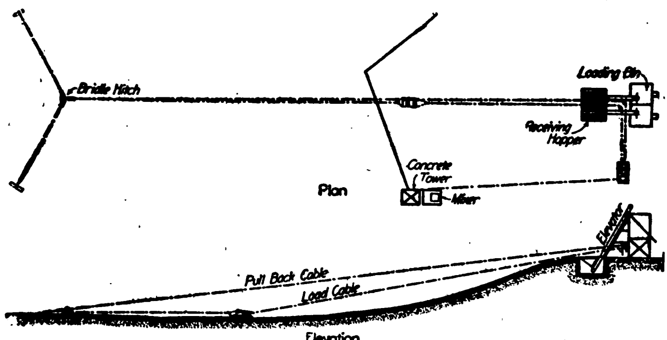


Fig. 11. Arrangement of Cables and Plant for Scraper-Bucket Basement Excavation.

the business center of Indianapolis, was carried out by using a power scraper which handled 12,000 cu. yd. of gravel in 18 days from an area of 70 x 200 ft. As installed the equipment consisted

of a Sauerman ¾-yd. scraper with pull and tail ropes, a three-drum, 75-hp. Thomas electric hoist, receiving hopper, two Link-Belt bucket elevators and two loading bins located as shown in the drawing.

As operated in this excavation a head-and-tail block served as a guide for the tail cable leading from the rear drum of the hoist to the rear of the excavator. The pull cable led from the front drum through a head guide block to the front of the bucket.

Forty-two teams were employed to haul the material away. Labor and other expenses amounted approximately to $20 per day, the output being nearly 700 cu. yd. per day.

Dragline Scrapers on Chicago Canal. On the Calumet-Sag channel of the Chicago drainage canal several drag-line machines were employed. On Sec. 2, in glacial drift during 1912, a Bucyrus dragline machine, equipped with an 85-ft. boom and with 2.5-yd. Page and Bucyrus buckets, averaged about 50,000 cu. yd. per month, working one shift of 10 hr. The average force employed was 10 men. On Sec. 4, a Marion self-propelling dragline excavator, with a 100-ft. boom, and a 3.5-yd. bucket for glacial drift and a 6-yd. bucket for peat and light material, excavated an average of 60,000 cu. yd. per month, working two 10-hr. shifts daily. The average force employed was 12 men per shift.

Armstrong Dragline in Montana. *Engineering and Contracting*, Sept. 2, 1908, gives the following: This machine consists of an upper platform rotated upon a lower frame. The frame is supported on skids and travels over rollers. A long boom and the power plant are carried on the upper platform. The scraper bucket of 1.5 cu. yd. capacity is pulled toward the machine. The machine travels under its own power away from the cut. These machines are made of wood or of steel. The machinery and iron work of the frame cost $4,500, and the lumber and erection labor about $1,000 more; a steel machine complete costs about $9,000.

The working weight is 45 to 50 tons, and the maximum capacity varies from 50 to 100 cu. yd. per hr.

The cost of operating a machine of this type, with a 48 by 96-in. vertical boiler, an 8 by 12-in. hoisting engine, and a 5 by 8-in. swinging engine during October, 1908, on the Huntley Reclamation Project, Montana, is given in Table I. A 2.5-cu. yd. bucket was generally used. The cut was 16 to 19.5 ft. deep, 12 to 15 ft. consisting of well compacted sandy soil, and the remainder of coarse gravel and sand saturated with water. The work during the month was difficult, the machine handling about 70% of its normal output. Two 8-hr. shifts were worked.

TABLE I. COST OF EXCAVATION WITH ARMSTRONG DRAGLINE EXCAVATOR

	Working time	Repair time	Lost time	Total time
Superintendent @ $125	$ 41.67	$ 6.26	$ 8.33	$ 56.26
2 dipper men @ $130	171.17	30.33	34.67	236.17
2 dipper tenders @ $95	125.08	22.17	25.33	172.58
2 firemen @ $85	111.92	19.83	22.67	154.42
2 groundmen @ $100	131.67	23.34	26.67	181.68
Team and driver hauling supplies @ $4	43.50	2.50		46.00
Laborers @ $2	21.75	1.25		23.00
Total labor cost, 16,000 cu. yd.	$646.76	$105.68	$117.67	$870.11
Labor cost per cu. yd.	$4.04	$0.67	$0.74	$5.45

Supplies:	
60 tons coal at $2.25	$135.00
10 gal. kerosene at 22 ct.	2.20
25 gal. gasoline at 25 ct.	6.25
10 lb. grease at 9 ct.	0.90
10 lb. graphite at 25 ct.	2.50
20 gal. engine oil at 31 ct.	6.20
25 gal. cyl. oil at 44.5 ct.	11.13
Total at 1.03 ct. per cu. yd. for supplies	$164.18
Total cost per cu. yd.	$6.48

Walking Traction for a Dragline Excavator. John W. Page, in *Engineering and Contracting*, July 19, 1911, gives the following: The excavator (Fig. 12) is mounted upon a turntable, which in turn is mounted on a platform consisting of I-beams. This platform is about twice as long as the turntable platform is wide. The turntable platform is arranged to roll upon it from one end to the other. The whole is supported on two "boats" or wooden skids. In moving, the machine is run to one end of the beam platform, thus removing the weight of the machine from the "boat" at the opposite end. This "boat" is then slipped ahead by means of cables operated by the main engine. Then the machine is run to the opposite end of the beam platform and the opposite "boat" is slipped forward. The operation gives the machine a zigzag walking motion, advancing it about 7½ ft. each time.

A Caterpillar Traction Dragline Excavator. A machine made by the Stockton Iron Works, Stockton, Cal., is described in *Engineering Record*, Dec. 12, 1914, by W. W. Patch. It is equipped with both a clam-shell and a dragline bucket, and weighs with either bucket about 20 tons. Its power is derived from a 20-hp. heavy-duty upright gasolene engine, operated with distillate. When traveling along the road in high gear the machine makes about ¾ mi. per hr. Under these conditions the jack arms are removed and are carried upon the deck, thus giving a maximum width of 15 ft. 6 in. At the intersections of 60-ft. roads turns

of 90° can be made readily. As the distance between the two axles is over 19 ft. there are seldom any highway stringer bridges which are subjected to a span load exceeding about 12 tons. The form of bucket bail is similar to that used in the Page drag scraper.

Both clam-shell and dragline buckets were provided, but the dragline bucket was used almost exclusively.

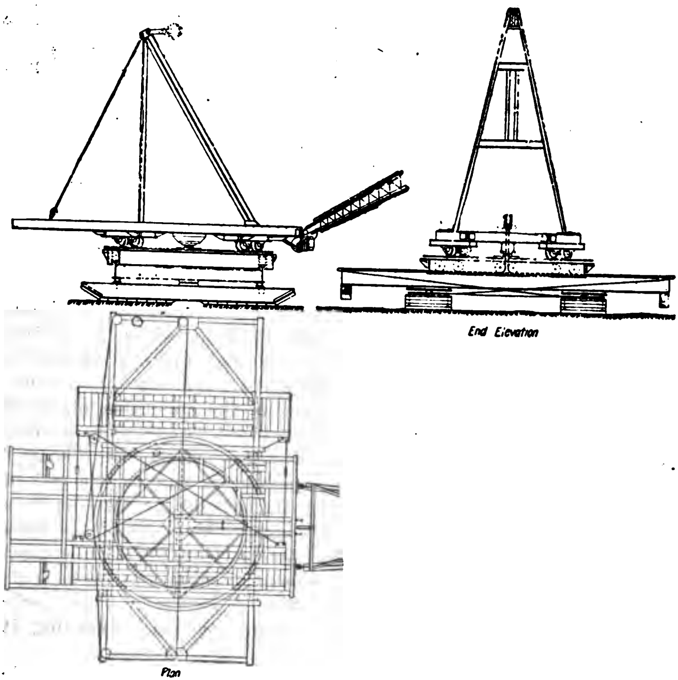
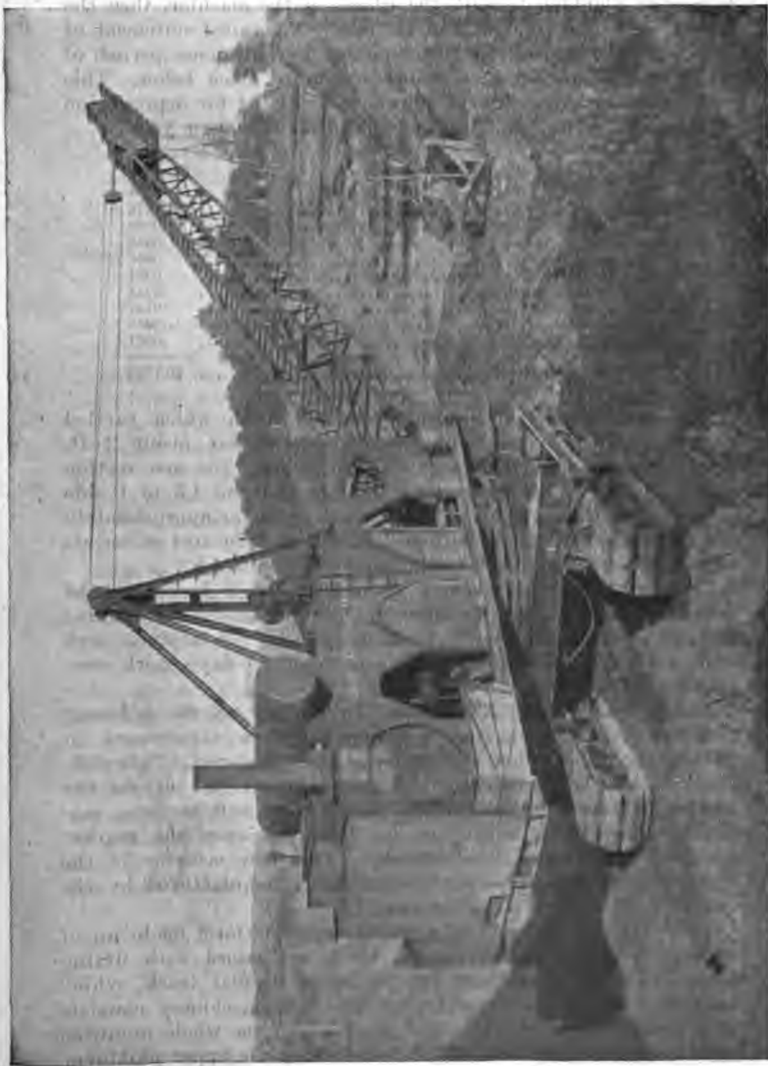


Fig. 12. Walking Attachment for Dragline Excavator.

When operating under the most favorable conditions this machine, with a crew of four men, has excavated 400 cu. yd. in a day of 8 hr. While for a period of seven months (Apr. to Oct., 1913) the average performance has been at the rate of 40 cu. yd. per hr., even when time lost on account of repairs and moving from place to place is included. This work was in southern Oregon. If blasting is required, or if the ground is so soft as



to require planking beneath the wheels of the machine, then the crew is increased to a total of six men. A detailed statement of the cost of operating the machine for a continuous period of seven months during this second season is given below. This statement contains a liberal allowance of $1,194 for depreciation of the plant. The total cost was $6,655 for 56,000 cu. yd.

	Cost per cu. yd.
Labor, men	$0.0476
Labor, horses	.0089
Explosives	.0058
Fuel, gasoline	.0052
Supplies (grease, oil, lumber, etc.)	.0094
Depreciation, machine	.0213
General expenses	.0127
Miscellaneous	.0018
Repairs	.0061
Total per cu. yd.	$0.1188

The work comprised deepening an old ditch which carried drainage water constantly. The old section was about 2 ft. deep, 4 ft. wide, and had 1.5 to 1 side slopes. The new section was 5 ft. deep, 5 ft. wide at the bottom and had 1.5 to 1 side slopes. The ditch was about 4 miles long, and for approximately one-half of its length the bottom 2 ft. was in indurated materials which required blasting before it could be excavated.

The crew comprised from 4 to 6 men and 2 horses at the following wages: Machine operator, $130 per month; gas-engine man, $80 per month; powder-man, $3 per day; 2 laborers, each $2.48 per day; 2 horses, each $1.25 per day. A day's work comprised 8 hr. on the job.

Jacobs Guided-Line Excavator. In the use of the ordinary drag-line bucket excavator, difficulty is often experienced in guiding the bucket when stiff material is encountered. This difficulty is especially noticeable when the bucket, in cutting the sloping banks of an open ditch, passes from stiff to loose material. Recently an excavator has been put upon the market designed to overcome this difficulty. This new machine is the Jacobs Guided-Drag-Line-Bucket-Excavator, manufactured by the Jacobs Engineering Co., of Ottawa, Ill.

This excavator consists of a steel-framed platform made up of standard structural steel shapes, which are joined with fitting bolts. This upper platform revolves on a circular track, which rests on a lower steel-framed platform. The machinery consists of a three-drum hoist with steel gearing and the whole mounted on a heavy cast-iron base, which is bolted to the upper platform. The machine swinging drums are operated by a double-cone

friction and are connected to the drum shaft of the hoisting engine by a sprocket and bushed chain.

The distinctive feature of the machine is the guide boom, which consists of a steel girder shaped like a figure J, with the hook end hanging vertically from a straight boom. Both booms are pivoted at the front end of the upper platform. The bucket, which is a rectangular steel box, open at the end toward the machine, is attached to a trolley which travels on the guide boom, having two double-flanged wheels riding on the upper flange and a third wheel bearing against the lower flange to keep the bucket from kicking upward. In making the cut, the bucket is hauled inward by a cable leading directly from the trolley to the engine. For dumping, it is hauled outward by the back-haul cable, which leads from the trolley to the head of the main boom and back to the engine. The bucket is dumped by continuing its travel to the vertical end of the guide boom, the boom being first swung around to the position at which the load is to be deposited.

The machine is self-propelling and travels on a track, which is made in sections and is moved by the machine itself.

This machine has been used for the construction of open ditches, tile ditches and back filling same, levees, roads and highways, etc.

This excavator is built in various sizes, from one having a ¾-yd. bucket and 25-ft. boom to one with a 1⅛-yd. bucket and a 40-ft. boom. The cost of the machines varies from $3,500 to $6,000, depending on the length of the boom and the capacity of the bucket.

At Dixon, Illinois, one of these machines constructed an open drainage ditch, having a 22-ft. bottom, a depth varying from 4 ft. to 6 ft. and 1½ to 1 side slopes. The machine used had a 40-ft. boom, a 1⅛-yd. bucket and was operated by a 7-in. x 10-in. double cylinder, 3-drum hoisting engine, with swinging drums sprocket driven from the front drum of the hoisting engine. The weight of the machine was about 23 tons, which included one ton of coal and 300 gal. of water. The average excavation for a 10-hr. day was 600 cu. yd. at the following cost:

Operator	$ 4.00
Fireman	2.50
Trackman	2.00
Coal	5.00
Oil and waste	1.00
Water	1.00
	$15.50
Interest, depreciation and repairs	10.00
Total per day	$25.50

For 600 cu. yd. this makes a cost of 4.25 ct. per cu. yd.

The material excavated was 4-ft. of gumbo and the substratum yellow clay. The yardage averaged 150 cu. yd. per station of 100 ft.

The labor employed consisted of an operator at $125 per month, a fireman at $2 per day, two trackmen at $1.75 per day, and a cook at $40 per month. The men were furnished with free board and lodging. Following is a tabulated list of expenses for 10.5 days.

Labor	$117.62
Coal	20.60
Coal hauling	25.00
Repairs	8.45
Camp supplies	9.72
Cook's wages	16.06
Traveling and livery	32.55
Insurance	7.14
Miscellaneous	7.14
Total, 10.5 days at $22.30	$234.28

Coal was hauled 8 miles from a railroad siding at a cost of 8 ct. per hundred-weight and part of the time at a cost of $5 per load. The item of "camp supplies" does not include some supplies used, which were on hand and not purchased during the month. "Traveling and livery" include a special trip to inspect work and attend commissioners' meeting. The output averaged 220 cu. yd. per day at a cost of 10 ct. per cu. yd.

The foregoing data are from "Excavating Machinery" by A. B. McDaniel.

A Locomotive Crane Used as a Dragline Excavator. *Engineering and Contracting*, May 10, 1911, gives data on the use of a locomotive crane on the New York State Barge Canal. This crane was bought to use for concreting, and while waiting for concreting to begin was rigged as a dragline excavator. It dug a channel 60 ft. wide on top, and 20 wide on the bottom, with an average depth of cut of 9 to 10.5 ft. and a length of 2,600 ft.

The crane began on April 14 and, in the 12 working days of the month, excavated about 6,000 cu. yd., according to the state engineers' estimate. There were two crews employed, each working 8 hr., and comprised as follows:

1 engineman at $100 per month.
1 fireman at $50 per month.
4 laborers at $1.60 per day.

The average cost of moving dirt has been about 9½ ct. per cu. yd.

The crane is a standard Brownhoist crane with 50 ft. of boom

built to handle 3 tons at a 48 ft. radius, with 12,000 lb. of ballast in the buck frame.

Dredging Gravel with a Weeks' Bucket. *Engineering and Contracting*, Feb. 5, 1913, gives the following. (See also Apr. 26, 1911.) Gravel for building purposes for the city of Vancouver, B. C., is obtained in part from submerged deposits, one of which lies at the mouth of Indian River at the head of the North Arm of Burrard Inlet. To obtain the gravel from this place over which the tidal range is about 12 ft., a Weeks patented bucket has been used in various ways since the spring of 1910.

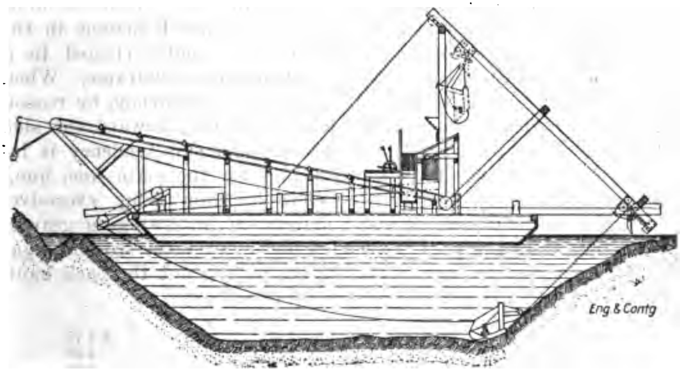


Fig. 14. Gravel Dredging and Washing Scow Equipped with Weeks Two Line Bucket.

First Plant. The first method of operating the bucket was from a skid A-frame mounting a swinging boom, on a scow. The bucket with its load is lifted and swung over the scow to be emptied and returned to its loading place by means of a ⅝-in. back-haul line passing from the hoisting engine over a sheave supported by a float suitably anchored. The bucket has a capacity of 24 cu. ft., and 35 cu. yd. of gravel per hr. is loaded when the distance the bucket transports its load is not over 200 ft.

It may be noted here that the tendency with this shovel wherever installed has been to make it a transporter of material as well as an excavator, with the inevitable result of reduced capacity and increased wear.

The operating crew consists of a foreman, engine runner, fireman and laborer, the principal duty of the latter being to spring the latch on the bucket which causes it to dump its load.

An 8¼ x 10-in. double drum hoisting engine burning 1½ tons

of coal per 10-hr. day, when working steadily, supplies the power. Through the top of the A-frame, a heavy link passes, at the rear end of which the backstays are fastened, and from the front end the boom hangs by means of a special shackle, the pin of which is enclosed by a couple of wearing sleeves. These sleeves are made of pipe and take the wear due to the swing of the boom. If kept well greased this wear is very small. At the point of the boom is a three-armed forging, the arms of which are set at equal angles. To the top arm is fastened the boom line of fixed length, and to one of the lower arms is hung a sheave for the 7/8-in. main line to the bucket. At the base of the boom is bolted a heavy bent plate, the long end of which fastens to the boom. The short end pivots between two angles riveted to a heavy plate which is bolted to the bottom of the A-frame. When the load comes upon the end of the boom, its tendency, by reason of the eccentrically suspended load, is to swing toward the side on which the main line sheave is hung, and this tendency is increased as the scow tips. A fair leader for the main line, hung in the A-frame, prevents this tendency from being excessive. With this arrangement of boom and tackle, no swinging gear is necessary. The sweep of the loaded bucket over the scow is regulated to a nicety by the engine runner paying out the back haul. The daily cost of operating is as follows:

1 foreman	$ 4.75
1 engine runner	4.50
1 fireman	3.00
1 laborer	2.75
1½ tons coal at $8	12.00
Wear and tear, depreciation, etc.	3.00
300 cu. yd. at 10 ct.	$30.00

Second Plant. Later a larger, but in every way similar, dredge was installed, and the original rig mounted for a time on pile bents instead of a scow. The object of this change was to facilitate washing and storing the gravel, which was done with a special type of washer, and the washed gravel elevated into bunkers. Owing to a desire to reclaim all the gravel possible from the fixed location of the dredge, the distance which the bucket hauled its load was made nearly 300 ft., which was too great to attain a large output. The depth of the pit to which dredging was carried was about 60 ft. below low tide. From 225 to 240 trips of the 1¾-cu. yd. bucket was all that could be averaged in 10 hr. Considerable time was lost, due to clogging of the washer by over-feeding. About 40 cu. yd. could be dredged per hr., washer permitting. The same crew was used as on the floating dredge, but the daily consumption of coal was greater by

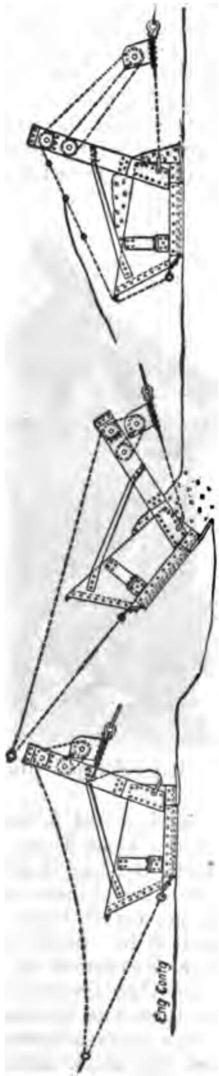


Fig. 15. Weeks Two Line Bucket in Successive Positions.

half a ton. The cost per cu. yd. was 9 ct., including all expenses.

Improved Plant. Wishing to reduce the length of haul, with its attendant wear and diminished output, a new method of operating has been devised, so that now the bucket digs under the scow (Fig. 14) upon which the washer also is mounted. An inclined trolley track projects beyond the front of the scow upon which runs a trolley car carrying a large sheave over which passes the main-haul lines. The trolley is locked at the lower limit of its

Fig. 16. Page Scraper Bucket.

run while the bucket is digging, and is unlocked by the bucket striking the releasing levers. Upon being unlocked, the trolley runs up the inclined track, the bucket being hung meanwhile from the trolley car by two hooks upon which it adjusts itself automatically and which prevent it from lowering or twisting. Arrived at the upper limit of its travel, the bucket dumps into a hopper, whence the gravel is conveyed by a belt to the washer. The bucket and trolley are then lowered to the bottom of the incline, and the bucket returned to its loading position by the back haul which passes over sheaves at the back of the dredge. Springs in tension absorb the shock of the descending trolley

car. The scow is held by adjustable anchor lines passing over the front corners and the middle of the stern.

The bucket now in use holds 1½ cu. yd. and averages 50 sec. per trip. Owing to a lack of sufficient scows for loading, no positive statement of its daily capacity can be made at this time, but it is known to be much faster than either of the other methods of operating. At present, the same crew as before operates the dredge, including the washer; but later, when the output becomes larger, an additional man may be required to assist in spotting scows.

The Weeks bucket is made by the Moran Co., of Seattle, Wash.

Dragline Excavator Buckets. They are of various shapes and are arranged either to tilt forward or rearward in dumping. The Page scraper bucket is illustrated in Fig. 16. It is dumped forward by holding the hoist line and slackening the pull line.

PAGE SCRAPER BUCKETS

Capacity cu. yd.	Width of cutting edge in.	Weight lb.	List prices, 1916
¾	36	1,450–2,200	$ 495– 575
1	45	1,500–3,500	546– 800
1¼	45–48	1,700–4,000	573– 875
1½	48	2,000–4,500	610– 938
2	51	3,000–6,000	750–1,094
2½	57	5,850–7,000	1,036–1,250
3	60	6,550–7,500	1,180–1,407
3½	60	7,000–8,000	1,313–1,563
4	60	8,600	1,688
4½	66	9,100	1,813
5	66	9,600	1,938

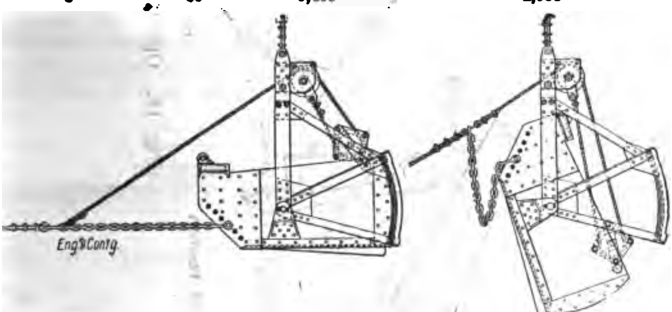


Fig. 17. The Holcomb Bucket.

The Monighan 2-line drag bucket is somewhat like the Page bucket. The Iverson is similar in form but is dumped by a third or latch line. The Hayward and Wenks buckets are dumped for-

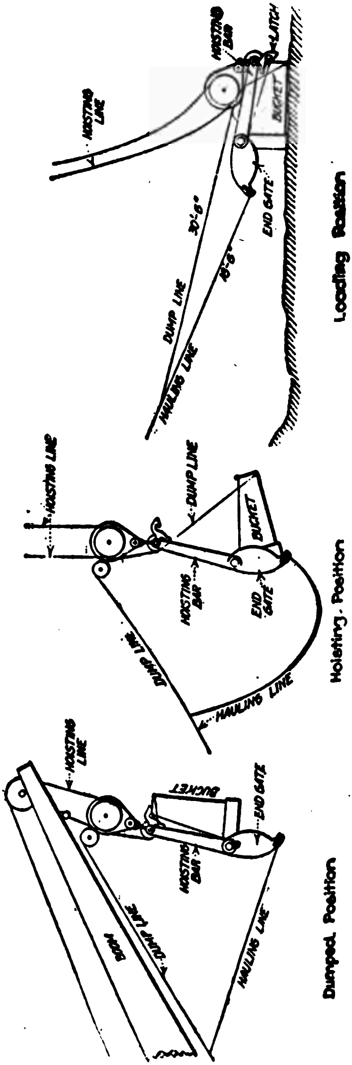


Fig. 18. Operation of Rapid Filling Dragline Bucket.

ward by pulling on the tail or hoist line, but the latter may be dumped backward by hauling on the pull line and slackening the tail line. The Browning bucket is dumped by a third line. In all, except the Iverson and Browning buckets, the drag line must be held against the lift line to prevent dumping.

The Sauerman drag line excavators are operated by one pull-line and a slack cableway. The bucket is drawn in one direction by the pull-line and allowed to slide in the other direction along the tightened cableway under the influence of gravity. It is dumped (either forward or backward according to the type) by encountering a stop on the cableway line. The prices of these machines depend upon the length of span, size of bucket, and local conditions. A ½-yd. excavator of 500-ft. span cost about $2,200 in 1916, and a 1½-yd. machine about $4,200, including cables, buckets, hoist and boiler, but not anchors, mast or tower timbers. The capacities vary from 10 to 80 cu. yd. per hr., depending on the size of the bucket, kind of material, and other conditions. With an average haul of 300 ft., about 35 cu. yd. per hr. per cu. yd. of bucket capacity will be averaged. About 30 hp. per cu. yd. of bucket capacity is required.

The Dunbar Dragline Bucket. This is described in *Engineering News-Record*, July 8, 1918. The bucket will take a load in traveling its own length, and then can be hoisted at once instead of being pulled to the bank of the drag line. The end gate holds the load, but at the same time allows water to escape. Experience showed that the cables lasted longer and the machine consumed less coal than when an ordinary bucket was used.

These buckets were designed by H. T. Dunbar, president of the Dunbar & Sullivan Dredging Co., Buffalo, N. Y. They were made at the company's machine shops on the work at Waterford, N. Y. They are of 3-yd. capacity.

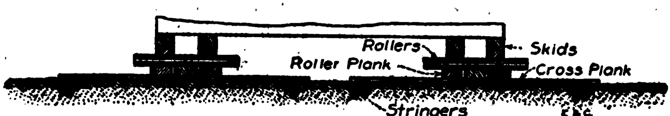


Fig. 19. Planking for Dragline Excavation Work Over Soft Ground.

Planking for Dragline Work Over Soft Ground. *Engineering and Contracting*, Dec. 16, 1914, gives the following: The sketch (Fig. 19) shows a method of planking for dragline excavation work for drainage ditch near Viro, Fla. The ground consists of a top layer of vegetable fiber on which a man can stand in most

places, but which will not carry a team. A 6-ft. bar can be shoved down its whole length with one hand. On 6 x 6-in. stringers laid parallel to the direction of movement are laid platforms of 3 x 12-in. x 12-ft. planks set close, and at the center of each platform is laid a roller track of three 6 x 12-in. x 14-ft. timbers set close. These track timbers are staggered to distribute the load to the plank. The stringers are pressed down into the ground by the weight of the excavator and apparently so confined the material as to prevent it from squashing out sideways under the ends of the planks. The stringers have to be dug out to be shifted ahead, but the planks can be easily picked up. Four pitmen pile the plank in bundles behind the machine which, with a chain hooked to the bucket, picks up, the bundles and swings them ahead for the pitmen to relay. The four pitmen, with the use of the machine as described, pick up and relay the stringers, plank and track timbers as fast as the machine can work.

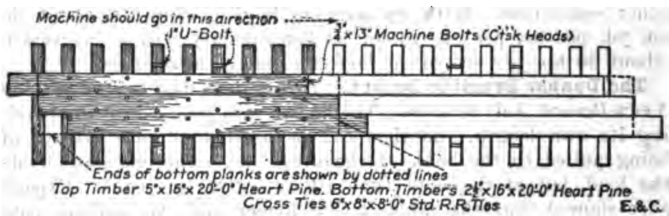


Fig. 20. Sectional Platform Tracks for Dragline Excavators.

Sectional Track for Dragline Excavator. Another form of plank track is illustrated in *Engineering and Contracting*, Feb. 17, 1915. The section is 24 ft. in length over all. Ten of these sections are used, five under each side of the machine, giving a track of about 100 ft. in length. Each section consists of three 5 x 16-in. x 20-ft. stringers laid side by side, thus forming a roller bed 4 ft. wide. Under these are placed ten 6 x 8-in. x 8-ft. standard railway cross-ties, spaced 2 ft. apart, as shown in Fig. 20. Under these are three 2½ x 16-in. x 20-ft. flooring planks, to serve as a stiffener, to elevate the roller bed and to keep the mud from forcing itself up between the ties. These three sets of timbers are bolted together by thirty ¾ x 13-in. machine bolts with heads countersunk below the surface of the top timbers. Four 1-in. U-bolts in the ties serve for hooking the swinging chains.

These sections may be swung ahead and placed in 1½ min. each. The machine has been moved 2,600 ft. in 10 hr.

Channon Excavator in Wet Gravel Pit. According to *En-*

gineering News, March 21, 1907, near Liberty Center, Ind., a 35-ton 1.5-yd. bucket, Channon excavator was used for stripping and excavating gravel from under water and loading it on standard railroad cars. The boom was 50 ft. long. The pit was 25 to 30 ft. deep, 15 to 25 ft. being in water. The overburden was heavy clay, of a nature difficult of plowing by four horses. A

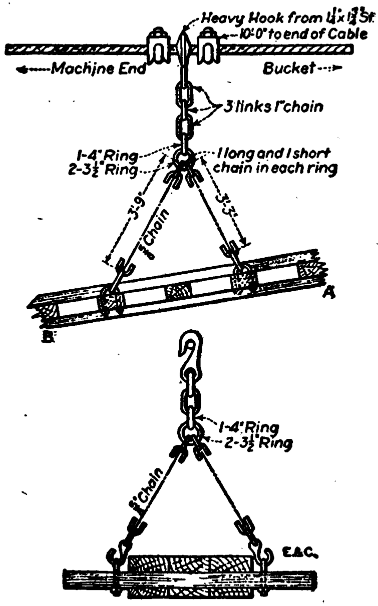


Fig. 21. Method of Hitching in Swinging Ahead Sectional Platform Track.

train of 7 cars, each of 26.5 cu. yd. capacity, was usually loaded in 60 to 75 min. About 40 to 60 cars were loaded daily.

Dragline Excavator on Sewer Work. *Engineering and Contracting*, Sept. 8, 1908, states that a Page and Schnable drag scraper bucket was used in excavating the first 6 or 8 ft. of a sewer trench in sand at Gary, Ind. The bucket was of 2 cu. yd. capacity, being operated on a 58-ft. boom with the usual cable and chain attachments. The derrick house worked away from the excavation. The machine was not used to its full capacity, but excavated about 60 ft. of trench per day, just enough to keep

ahead of the other forces which were arranged to complete 60 lin. ft. of sewer per 9-hr. day. The average swing made by the bucket was 90°. In turning the bucket in its various operations, it was found that the average time for each motion of the bucket was as follows:

Swinging from embankment	5 sec.
Lowering to trench	5 sec.
Digging	15 sec.
Hoisting full bucket	5 sec.
Swinging to embankment	5 sec.
Dumping	5 sec.
Total average time	40 sec.

Thus 30% of the time of operation is consumed in digging.

From 400 to 600 cu. yd. per day, place measurement, were excavated, the material being dumped on the side of the trench. The best day's work, 850 cu. yd., was accomplished in 5 hr. digging time.

On this work it was found that the bucket dumped better if enough water was kept in the pit to make the material a little sloppy.

Dragline Excavator Work on the N. Y. Barge Canal. *Engineering and Contracting*, Mar. 23, 1910, gives the following:

The material moved was 10% mud and 90% hard material. The dragline excavator was operated by three 8-hr. shifts, each shift consisting of: 1 operator, 1 fireman, 1 foreman and 4 pit laborers. From March 25 to April 14, 1909, inclusive, the following work was done.

The machine worked 21 days, advanced 1,635 ft. and excavated 19,725 cu. yd. or 940 cu. yd. per 24-hr. day. The best work was 1,467 cu. yd. for the three shifts of Apr. 2. All repairs which could be postponed were made during the shift from 8 P. M. to 4 A. M. Out of the 69 hr. lost time, 46 hr. were for broken shafts. These were broken on the dragline drum and were chiefly the fault of the operators. The remaining 23 hr. lost time were because of cable and bucket breaks.

Dragline Work on Chicago Channel. *Engineering and Contracting*, Aug. 4, 1909, gives the following: Section 1 of the North Shore Channel of the sanitary district of Chicago includes 3,350 ft. of channel excavation, 40 ft. wide at the bottom, 80 ft. wide at the top, with an ultimate depth of water 13.5 ft. Part of this section was done by the day labor system, as the district owned a steam shovel, dump car, and locomotive plant; also because by doing itself certain portions of the work, where interference with property rights was greatest, the district could

avoid trouble with adjacent property owners; and because a long haul was necessary, and all spoil had to be removed from the right of way.

The top-soil on both these sections was excavated with team and drag scrapers. In this way 47,000 cu. yd. were removed from Section 4, and 21,000 cu. yd. were removed from Section 5. The balance of the cut was made with Heyworth-Newman excavators, one machine working on each section. These machines are designed and operated by Jas. O. Heyworth, who has patented the machine and bucket and is manufacturing them.

These sections were in dry excavation, all material being stiff blue clay. Working continuously on Section 4, from Sept., 1908, to Dec., 1909, one scraper excavated 499,000 cu. yd. in 16 months, or 31,191 cu. yd. per month; the best month being 52,163 cu. yd. in March, and the worst being 15,517 cu. yd. in December.

On Section 5, during 6 months from May to October, the average output was nearly 30,000 cu. yd. per month; but during November only 1,000 cu. yd. were moved, and 16,000 in December. Hence the 8-month average was 25,214 cu. yd.

An estimate of the cost of labor for one machine is as follows: No consideration is taken of interest on contractors' bond, insurance, or of general office expense. The work was divided into three shifts of 8 hr. each for the operators, and two shifts of 12 hr. each for the balance of the crew. The work was carried on 6 days a week or 25 days a month. The figures were obtained by the editor while going over the work and are given according to the information furnished him. He believes, however, that the crew given for each machine is too large. It would be more nearly correct to eliminate the items of mechanic, blacksmith's helper and oiler, and to divide the blacksmith's time between three machines.

12 laborers at 20 ct. per hr., per month	$ 720.00
3 operators at $150 per month	450.00
2 firemen at $90 per month	180.00
1 man and team at	125.00
1 superintendent to 2 machines at $200 per month	100.00
1 civil engineer and timekeeper, $125 — 2 machines	67.50
1 mechanic, 3 machines at $150	50.00
1 blacksmith, per month	90.00
1 blacksmith's helper, per month	50.00
1 oiler, per month	60.00
Total per month	$1,892.50

Using 31,191 cu. yd. excavated for Section 4 and 25,214 cu. yd. excavated for Section 5, the costs per cu. yd. are estimated as follows:

Section 4

	Cost per cu. yd.
Labor	$0.061
3 tons coal per day	0.010
Repairs and miscellaneous supplies	0.048
15% annual interest on $15,000 plant	0.006
50% annual depreciation on $15,000 plant	0.02
Total cost per cu. yd.	$0.145

Section 5

	Cost per cu. yd.
Labor	$0.076
3 tons coal per day	0.012
Repairs and miscellaneous supplies	0.059
15% annual interest on $15,000 plant	0.007
50% annual depreciation on $15,000 plant	0.030
Total cost per cu. yd.	$0.184

The labor item includes all work done, such as repairs, moving machine, and actual excavation.

The repair and miscellaneous supplies item is large. It contains new cable, oil, renewals and 2 miles of 2-in. pipe to supply water to the boilers. The strains and work demanded of large dragline machines are heavier than that of steam shovels. The average repair and maintenance bill has been $1,500 per month.

Dragline Excavator Work at Stockton, Cal. *Engineering and Contracting*, July 20, 1910, describes work on a diverting canal built to prevent floods at Stockton, California. The canal is 5.25 miles long with a cross-section 150 ft. wide on the bottom, and with side slopes of 1 to 1½. Two dragline excavators were used, one a Heyworth-Newman machine having a 100-ft. boom and a 3½-cu. yd. bucket. The second machine had a 110-ft. boom and had been converted from clam-shell to dragline rig. It used a 2½-cu. yd. bucket.

The method followed in doing the work was to set up the Heyworth excavator 7 ft. from the center line of the channel in order to control the excavation of the outer 30 ft. opposite the levee side. This allowed the boom to deposit the spoil on the levee site clear of the berm. When about 2,000 ft. of progress had been made in this manner, the machine was placed in about 31 ft. and another section was taken out up to 7 ft. of the levee side. The converted clamshell machine followed, taking out the remnant. The excavating machines were all mounted on rollers, made of 8-in. extra heavy hydraulic pipe, with pine centers pressed in, and were moved forward on 12 x 14 in. timbers.

The organization under which the work was done consisted of the following:

1 superintendent.
2 captains, 1 on each machine.
3 leveemen, 6 hours on and 12 off.
2 mates, 1 on each machine.
4 firemen, 2 on each machine.
8 deckhands.
1 blacksmith.
1 helper.
1 cook.
1 flunkey.
2 pumpmen.
1 handyman.
1 team of 6 horses for hauling oil and freighting.

The expenditure per month was as follows:

Pay roll	$3,754
Fuel oil	945
Lubricating oil and repairs	2,220
Total	$6,919

To this amount must be added the overhead expense, plant cost and interest on the money invested. The contract price paid for doing the work was 15½ ct. per cu. yd.

The above prices paid for labor included board. On account of the extent of the work, it was necessary to have a camp that could readily be moved. The camp consisted of two large tents which were used as sleeping quarters by the men and two smaller tents for the engineers, superintendent and captains, also serving as offices. A cook wagon, of the same type as are used on the ranches, was used both for doing the cooking and as mess tent. This outfit proved satisfactory from every standpoint.

From Apr., 1909, to Apr., 1910, inclusive, the Heyworth-Newman machine excavated 437,873 cu. yd., and the converted clam-shell machine 242,600 cu. yd. The average monthly output for thirteen months with the Heyworth-Newman machine was 33,683 cu. yd. The converted machine worked 10 months and had an average output of 24,260 cu. yd. Taking the expenses given we have a cost of nearly 12 ct. per cu. yd. without overhead expenses.

Dragline Work on Irrigation Canal. E. H. Moritz and H. W. Elder, in *Engineering and Contracting*, Sept. 11, 1912, give the cost of dragline excavator work on the enlargement and improvement of the Main Canal of Sunnyside Yakima Project, Washington. About 23 miles of the canal were excavated with a Lidgerwood-Crawford dragline machine. This machine was erected in January and February, 1909, and began operating at the upper end, working down stream. A road had to be leveled ahead of the machine, and all material not needed was dumped on the other side of the canal. The extra amount of road grading was not anticipated in the original schedule, and the addi-

tional work that had to be done to strengthen the levee, caused the unit price to run higher than was anticipated.

A great deal of team work had to be done in connection with the machine excavation. The profile of the upper bank was very irregular, and it meant that the old levee had to be almost destroyed. A roadway, 8 ft. wide had to be built, and as the grade could not exceed 5%, the hills had to be cut down and the ravines filled up. Where the necessary cut on hills exceeded 5 ft. the cut had to be 20 ft. wide to permit the car to swing and dump. In very deep cuts, this placed the machine so far below the level of the natural ground that it was very difficult

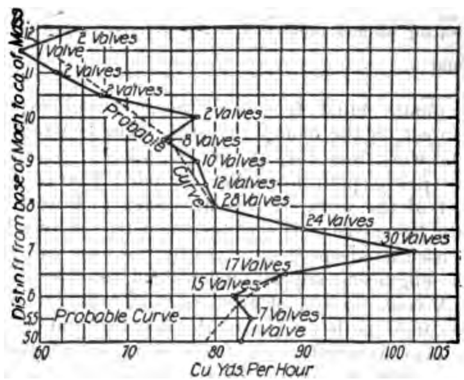


Fig. 22. Curve Showing Performance of Dragline Excavator.

to dispose of the material, because of the lack of dumping space. In some cases the road grading was 30% of the entire excavation in cut, and as the material was often hauled 200 ft. or more to the fill ahead, the cost was high. This cost was charged against the machine, and the total cost distributed into the total yardage.

An attempt has been made to show the amount of material moved per hr., with the machine operating at various heights above the center of gravity in the mass excavated. The result is shown in Fig. 22. As indicated each point represents the average of a number of values, and for each value a reach was selected over which the material and conditions of operation were of an average nature. The curve shows that the maximum yardage per hr. was obtained with the machine excavating a mass whose center of gravity was 7 ft. below the base of the track. This

diagram is of interest as showing the effect the depth of cut has on the cost of excavation.

The excavation was done under water during 7 months of the year. During the winter months, when there was no water in the canal, frost interfered with the work to a considerable extent. Due to the shape of the section, the time consumed in lifting and cleaning the buckets was probably considerably greater than for most excavation where a similar quantity of material is moved.

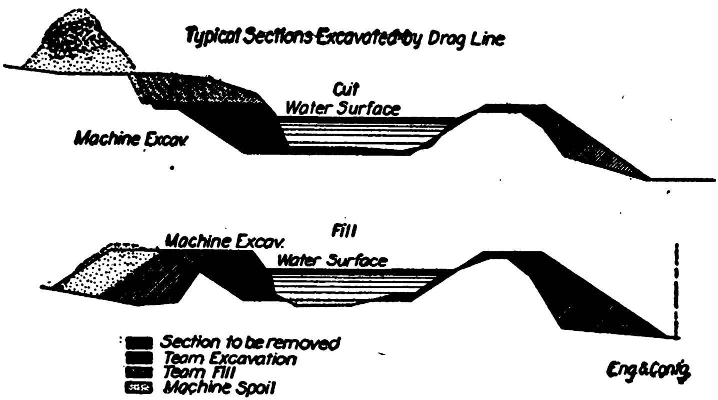


Fig. 23. Typical Sections Excavated by Dragline Excavator.

COST DATA — DRAG LINE EXCAVATION, 204,183 CU. YD.

	Per cu. yd.
Labor, excavator	0.027
Labor, spoil banks	0.031
Fuel	0.015
Plant maintenance	0.035
Plant depreciation	0.008
Total per cu. yd.	0.116

Force and wages — One crew consisted of 6 men and 2 horses.
Wages paid — Engineer, $4; fireman, $2.85; groundman, $2; man and team, $4.50.
Miscellaneous — Maximum excavation per 8-hr. shift, 1,170 cu. yd.; maximum excavation for week, 16,000 cu. yd.; average excavation per 8-hr. shift, 545.5 cu. yd.; average excavation per actual working hour, 93.7 cu. yd.

Bridge Foundation Excavation. C. H. Johnson states that the Nashville, Chattanooga and St. Louis R. R. has completed abutments for a bridge across Chattanooga Creek, the foundations of which called for the excavation of 40,000 cu. yd. of material, about

two-thirds of which was on the south side of the creek. The excavation had to be taken out to about 5 ft. below the water surface and the maximum depth of cutting was 42 ft. A Bucyrus dragline with a working radius of 70 ft. horizontally and 50 ft. vertically was rented from a contractor, who also furnished the men to operate it. The excavation made for the two arches as originally planned was refilled by this machine, a half-inch stream of water being thrown on the material as it was dumped from the bucket. As the material was already wet, part of it coming from below the water surface, this stream proved sufficient to make it flow so as to fill the entire excavation. The daily expense of operating the machine was as follows:

Rent of machine	$25.00
Foreman	4.00
Engineman	6.00
Fireman	3.60
Six laborers	10.50
Pumper	2.00
Watchman	3.00
Machinist	4.00
Coal, repairs, oil, etc.	5.90
Total per day	$64.00

The total cost of excavating 40,000 cu. yd. was $9,739, or 24.4 ct. a yd. However, about half the material had to be handled twice on account of the difficult location of the work, and allowing for this the cost was 16.2 ct. per yd. of material handled. This rather high price for drag line work was due to the fact that it was necessary to pull the old piles with the machine and also because of the many boulders which were encountered.

Cost of Excavating Drainage Ditch with a Drag Line Excavator. Ray S. Owen, in *Engineering and Contracting,* Mar. 11, 1914, gives the following: The following is a statement of the cost of excavating drainage ditches in Rock County, Wis. The machine used was a drag line dredge with steam power, running on a track laid by hand and propelled by pulling on a deadman with the hoisting drum. The operating crew consisted of 1 runner, 1 fireman, 2 trackmen and 1 teamster.

The ditches are in a hay meadow, the soil being about 2 ft. of muck underlaid by sand. The ditches averaged 5 ft. deep with 1½ to 1 slope, the main ditch, 2.60 miles in length, having a 6-ft. bottom with 21-ft. top and the lateral 1.36 miles in length, having a 4-ft. bottom with 19-ft. top. The total excavation computed for the ditch was 53,019 cu. yd. The soil caved very badly and a large amount of excess material had to be excavated to get the specified prism clear of dirt. The amount of dirt actually moved was about 75,000 cu. yd.

The two ditches are not connected but empty into Sugar River at points about one-quarter mile apart. This arrangement necessitated a tear down and move of about three miles from the end of one ditch, after it was completed, to the other ditch, and a set up.

The costs include freight on machine from Madison, Wis., to Sterling, Ill., the operation, moving, repair, etc., of the machine during the work, and the tearing down and delivery of the machine on board cars at Sterling, which is about 8 miles from the job. The rent of 2 ct. a yard included the furnishing, by the owner of the dredge, of sheaves and cable, which was a large item as the sand wore them out very rapidly. The cost of coal, teaming and moving is rather large, because of very bad roads when the outfit was moved out in the spring and the deep sand through which the coal was hauled during the summer. The unit prices are given for the contract yardage and for the actual yardage of 75,000 cu. yd.

	Per cu. yd.
Rent of dredge	$0.014
Labor	0.038
Coal	0.006
Express and freight	0.002
Bond and liability insurance	0.002
Livery and carfare	0.001
Oil	0.000
Teaming and moving	0.008
Tools, supplies, repairs, lumber	0.002
Miscellaneous	0.001
Total cost per cu. yd.	$0.074

The total cost per cu. yd. of contract yardage was 10.5 ct.

This shows that it was necessary to make 42% excess excavation with the drag line machine.

Five Examples of Cost of Dragline Excavation. D. L. Yarnell, in *Engineering and Contracting*, Feb. 2, 1916, gives the following:

Job 1. A dragline excavator of the rotary type, having a 2-yd. scraper bucket and a 60-ft. boom, was used in the construction of drainage ditches in southern Texas. It was built mostly of wood and moved on rollers. Power was derived from an 80-hp. internal-combustion engine, burning oil. The cost of the excavator, ready to operate, was $12,000. It was operated about 10 months in two daily shifts of 10 hours each, a shift consisting of 10 men. The actual working time was not recorded. The ditch ranged from 4 to 22 ft. in bottom width, from 3 to 12 ft. in depth, and had 1 to 1 side slopes. The soil varied from a stiff, heavy clay to a fine sand. The excavation amounted to 230,000 cu. yd. The cost was as follows:

Operating expenses	$22,313.36
Miscellaneous expenses	374.70
Interest and depreciation	4,100.00
Total	$26,788.06
Cost per cu. yd., $0.1164.	

Job 2. On another drainage project in southern Texas, a 2-yd. rotary excavator was used. The machine was of steel throughout, had a 60-ft. boom, and was mounted on caterpillar traction. The crew consisted of a foreman, operator, engineman, oiler, and two laborers. The machine was operated by a 110-hp. internal-combustion engine, with oil as fuel. The total cost of the machine was about $17,500. The cost of erection was $509. During the four months of operation two 10-hr. shifts were run. The ditches ranged from 4 to 22 ft. in bottom width and from 3 to 12 ft. in depth, with 1 to 1 side slopes and 8-ft. berms. The material excavated was a stiff, heavy clay. The excavation amounted to 91,400 cu. yd. The cost was as follows:

Operating expenses	$ 8,873.82
Miscellaneous	371.00
Interest and depreciation	2,391.00
Total	$11,635.82
Cost per cu. yd., $0.1273.	

Job 3. In the same general locality as the last example a 1½-yd. rotary dragline excavator, operated by a 50-hp. internal-combustion engine and mounted on caterpillar traction, was used in the construction of some ditches in soil ranging from stiff, heavy clay to fine sand. The ditches were of the same dimensions as in Job 2. The machine was rebuilt from an old dipper dredge at a cost of about $1,200. It was operated in two daily shifts of 10 hr. each. The crew for each shift consisted of from five to six men. During the five months of operation the machine moved 59,014 cu. yd. at an expense, exclusive of interest and depreciation, of $8,921, or $0.1512 per cu. yd.

Job 4. A rotary dragline excavator with a 2¼-yd. bucket and 65-ft. boom, mounted on skids and rollers, was used in the excavation of 222,500 cu. yd. in South Dakota. The power was obtained from a 50-hp. internal-combustion engine, using gasoline. The cost of the machine, complete, was $10,500. The total time of construction was 148 working days, or approximately six months, of which 23 days were occupied in making repairs. Two shifts of 11 hr. each were run. The soil was a loam underlain by clay. The crew and rates per month were as follows: One superintendent, $125; 2 cranemen, at $100; 4 trackmen, at $50; 1 teamster, $45; 1 cook, $40. The operating expenses were as follows:

Gasoline, 15,444 gallons, at $0.124	$ 1,915.05
Labor	3,060.00
Subsistence	561.81
Cables	978.87
Repairs and renewals	845.93
Miscellaneous	2,078.72
Interest and depreciation	2,152.50
Total	$11,592.88

Cost per cu. yd., $0.0521.

Job 5. The following costs were secured on the operation of a rotary dragline excavator with an 85-ft. boom, 2-yd. bucket, and a 50-hp. engine. The work was done on the New York State Barge Canal. The machine weighed 147 tons and cost $10,000. It excavated earth 90 ft. from center on one side and deposited it 100-ft. from center on the other. It dug a channel 25 ft. deep and deposited the material on waste bank 15 to 25 ft. high. The material was a stiff clay, with few stumps or boulders. The following is a condensed cost record for five months' work:

	Total for month	Yards excavated
April	$1,088.21	5.205
May	1,041.53	18,365
June	1,152.04	25,333
July	1,317.61	33,055
August	1,535.36	47,363

Average cost per yd. for 5 months, including all charges, $0.047.
In May, items of cost were as follows:

Engineman, at $90 per month	$ 90.00
Engineman, at $95 per month	84.04
Fireman, pumpmen, watchmen, etc., at $1.75 per day	363.00
Coal, at $3 per ton	147.00
Repairs, including labor and material	15.82
Interest and depreciation	341.67
Total for May	$1,041.53

Large Electric Dragline Excavators. *Engineering and Contracting*, Jan. 22, 1913, gives information as to Lidgerwood-Crawford machines built for use on the Calumet Sag Channel, in Chicago. The machines weigh 120 tons each, and operate 2½-cu. yd. Page buckets on 100-ft. steel booms.

The arrangement of the operating machinery is shown in Fig. 24. The double drum hoist is operated directly by a gear on the shaft of a 112-hp., 60-cycle, 3-phase motor, making 690 r.p.m. A 52-hp., 60-cycle, 3-phase motor, 855 r.p.m., operates the bevel swing gear as shown. The air brakes are operated through power furnished by a 25-cu. ft. motor-driven air compressor. The current is furnished by a public service company and is brought from Blue Island, several miles away, over a high tension line at 33,000 volts to a transformer house on the work

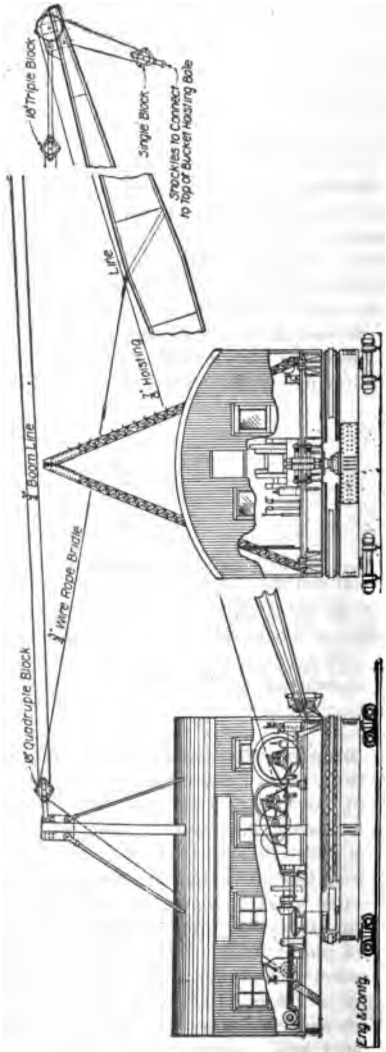


Fig. 24. Arrangement of Operating Machinery on Electric Dragline Excavator.

where the voltage is stepped down to 2,300 volts. It is again stepped down to 440 volts through a portable transformer which is attached to the dragline machine by a cable and is pulled along on its trucks as the machine moves ahead. On the machine the current is stepped down to 110 volts for the incandescent lamps and to 35 volts for the searchlight which is placed on the front of the house and just under the boom.

The machine is operated by two men on board and two men outside for handling the track. While moving to position for commencing work one of the machines was moved 410 ft. in one day.

Electric Draglines on the Sun River Irrigation Canal. Owing to the distance of this work from the nearest railroad and difficulty of hauling over poor roads, electric power was adopted for all machinery. *Engineering Record*, Jan. 29, 1916, gives a description of the work.

Current was obtained from the Great Falls Power Co.'s plant at Rainbow Falls, 75 miles away. It was transmitted at 48,600 volts over wires strung on 45-ft. cedar poles with a span length of about 350 ft. Each conductor was three-strand copper wire, carried by suspension insulators on wood cross arms. A fourth stranded steel cable was grounded at each pole to help keep the line clear of static disturbances.

At canal miles 1, 20 and 36 power was delivered to substations of 700 to 1,600 kva. capacity, where the voltage was reduced from 48,600 to 16,500 for distribution along the canal. The distribution line was on 30-ft. fir or cedar poles with span lengths of 150 ft. The circuit was three copper wires with pin-type insulators on single wood cross arms, and no ground wire was used.

Two Bucyrus dragline machines were used for excavation. The larger was Model 24 equipped with a 100-ft. boom and an extra heavy 3½-yd. Page bucket. The smaller machine was Model 20 with 85-ft. boom and 2½-yd. bucket. For transforming the 16,500-volt line current down to the voltage required by the motors, two sets of transformers were required. One set, stepping from 16,500 to 2,200 volts, was mounted on heavy trucks and hauled along by teams as the work proceeds. Connection was made to the 16,500-volt line at some convenient point and current transmitted at 2,200 volts through a triple-conductor, steel-armored cable to the second set of transformers. These were mounted under the floor on the frame of the machine, and step the current down to the 440 volts required by the motors. The steel cable was about 1,000 ft. long and obviated the necessity of moving the high-tension connnection when the line was alive,

as the machine could move along 1,500 ft. or more without moving the transformers.

Roads for Sidehill Work. It was expected that the handling of the machines on sidehill slopes as steep as 2½:1 would be slow and probably dangerous. Whenever sidehills were encountered the machines were used to excavate and level ahead of themselves a road from 30 to 35 ft. wide, on which the timber track was laid. This advance grading was at such elevation as would produce the most efficient work of the bucket and still keep the track excavation within the lines of the completed canal, thereby rendering unnecessary any non-productive excavation by the machines. At several points on the canal the upper cuts were as great as 90 ft. By excavating the grade of the track 50 ft. above canal grade, however, the upper part of the slope was excavated without double handling of the material. The engineers state that the machines far exceeded the expectations of the contractors in their ability to dig down on a 1½:1 slope and load the bucket to capacity.

The material excavated varied from a gravelly loam to cemented gravel, glacial drift and sandstone, and the topography from a level prairie to a steep, rocky hillside with transverse slopes of 2½:1. In the heaviest material blasting was resorted to, but in several instances the machines have dug 8 or 10 ft. of seamy sandstone without the use of explosives. About 1,500,000 cu. yd. of excavation has been handled by these two machines in two seasons, and costs are given here for some of the work, showing the nature of the material handled and the working conditions.

Power consumption has varied from 0.8 to 3.0 kw.-hr. per cu. yd. of material moved, depending on the nature of the material. No attempt was made to obtain record-breaking outputs for the machines, as it was realized that with frequent moves, rough topography and the condition imposed of placing the material so as to produce a watertight bank, outputs would not be comparable with those of machines working in a large pit and wasting the material or loading it into cars. Outputs of 1,450 cu. yd. per 8-hr. shift and 32,000 cu. yd. per shift per month have, however, been obtained under the above conditions. The crew required to operate a machine for one shift has been one operator at from $175 to $200 a month, one oiler at $2.50 a day, four trackmen at from $2 to $2.50 a day and one team to move track timbers, etc. Electrical work for all shifts has been performed by an electrician or electrical foreman who received from $150 to $175 a month.

Interest on investment includes all charges for insurance, bond premium and interest on cash capital required. Preparatory ex-

pense includes all charges for the delivery and installation of plant and accessories. Plant depreciation includes all charges for repairs and depreciation of tools and machinery. Under the classification adopted for excavation, class 1 includes all material that can be plowed to a depth of 6 in. with six animals of 1,400 lb. or over, and boulders of less than 2 cu. ft.; class 2 includes indurated material that cannot be plowed to a depth of 6 in. with six animals, but after being loosened can be excavated by teams and scrapers, and also boulders from 2 to 10 cu. ft. in size; class 3 is rock in place not included in classes 1 and 2.

TABLE I. EXCAVATION COSTS IN CENTS PER YARD WITH MODEL 24 ELECTRIC DRAGLINE VALUED AT $36,326

	Class 1, 333,689 cu. yd.	Class 2, 23,319 cu. yd.	Class 3, 39,045 cu. yd.
Interest on investment	0.81	1.21	2.25
Preparatory expense	1.33	1.99	3.73
Plant depreciation	3.63	5.41	10.12
Executive	0.89	1.24	3.09
Labor	5.98	7.85	21.03
Electric power	0.73	1.03	1.82
Supplies	1.13	1.67	6.72
Miscellaneous	0.16	0.15	0.29
Total	14.66	20.55	49.05

TABLE II. EXCAVATION COSTS IN CENTS PER YARD WITH MODEL 20 ELECTRIC DRAGLINE VALUED AT $20,957

	Class 1, 410,747 cu. yd.	Class 2, 4,180 cu. yd.	Class 3, 9,546 cu. yd.
Interest on investment	0.44	0.76	1.61
Preparatory expense	1.12	1.20	2.52
Plant depreciation	1.86	3.22	6.79
Executive	0.71	1.31	3.14
Labor	3.70	8.22	15.77
Electric power	0.78	1.78	2.80
Supplies	1.29	1.53	7.50
Total	9.90	18.02	40.13

Costs for the Model 24 dragline are for the construction of 2 miles of canal on heavy sidehill and ½ mile of canal entirely in cut. The sections excavated were from 12 to 22 ft. in bottom width with side slopes of 1:1 and 1½:1. Costs include the hand trimming of 9,000 ft. of the canal for placing concrete lining.

Costs for the Model 20 dragline are for 5 miles of canal with 22-ft. bottom, and 4 miles of canal with 27-ft. bottom. Side slopes in both cases are 1½:1. The topography was rough, rolling foothill country, with the surface covered with large boulders. About 25% of the canal was wet in the bottom from springs.

Steam and Electric Draglines on N. Y. Barge Canal. Work done on Contract 42, New York State Barge Canal, was partly done by dragline excavators. According to *Engineering and Contracting*, Sept. 28, 1910, the material handled consisted largely of black gumbo, near Utica.

The following data show the costs of excavation per cubic yard for the month of April, 1910. These costs include labor, repairs and distribution of field office expenses:

Heyworth-Newman Excavator, 100-ft. Boom; 2½ Yd. Bucket:

1 operator	$ 4.00
1 foreman	2.00
5 laborers	7.50
1 foreman, average $85 per month	2.83
1 pumpman	1.50
1 oiler	2.00
1 team 1 shift a day	4.50
Total cu. yd. for April	23,192
Total cost for April	$1,983.84
Total cost per cu. yd.	$ 0.085

Hydraulic Dredge "Mohawk," 12-in. suction:

1 captain, per month	$ 150.00
3 enginemen, per month	75.00
3 levermen, per month	110.00
1 mate, per month	120.00
6 deckhands, per day	2.00
3 firemen, per day	2.00
8 laborers or pipemen, per day	1.60
Total cu. yd. excavated	15,557
Total cost	$1,726.30
Cost per cu. yd.	$ 0.111

Two Lidgerwood Excavators, Electrically Operated, with 25 hp. Motor for Swinging and 125 hp. Motor for Hoist; 2½ Yd. Page Bucket:

1 operator, per day	$ 4.00
1 oiler, per day	2.00
5 laborers, per day	1.50
1 sloper, per day	2.25
1 foreman, $85 per month	2.83
1 electrician, $125 per month	4.17
Total cu. yd. excavated Machine No. 1	2,271
Total cost	$1,667.80
Cost per cu. yd.	$ 0.735
Total cu. yd. excavated by Machine No. 2	2,583
Total cost	$ 992.30
Cost per cu. yd.	$ 0.384

The two Lidgerwood machines worked only part of the time during this month, No. 1 working 13 days and No. 2 working 10 days during the month. Both were engaged in moving to new positions and were working at a disadvantage. The yardage for these machines should be about the same as for a Heyworth-Newman machine under similar conditions. The difference in daily pay roll is, however, in favor of the electrically driven machine.

The electric power on these machines costs about 1 ct. per cu. yd. City current is used and a transformer is placed at convenient points along the line, as the machine moves ahead.

The repairs on the Heyworth machine have averaged, approximately, $400 per month. The highest amount charged to repairs for any one month is $667.

Another machine used on this work was a cableway with dragline bucket. It consists of a movable tower, located on one side of the canal with a cable running from it to an anchorage on the opposite side of the canal. The drag bucket is supported by and slides up and down this cable. It is pulled back and forth by an endless line. The crew and costs are as follows:

1 operator, per day	$ 4.00
1 fireman, $75 per month, per day	2.50
1 foreman or supt., $200 per month, per day	6.67
1 pumpman, per day	1.50
6 laborers, per day	1.50
Total cu. yd. excavated	15,065
Total cost	$1,455.81
Cost per cu. yd.	$ 0.096

This tower is 85 ft. high and operates a 1⅞-cu. yd. bucket with a 10 x 12-in. hoisting engine and 40-hp. boiler. This machine is becoming quite popular along the canal because of its adaptability and its moderate cost.

Steam and Electric Draglines on Ditch Work. F. N. Cronkolm, in *Engineering Record*, Dec. 26, 1914, gives the following: The operation of steam and electric dragline excavators and an electrically-driven suction dredge are described and costs of excavation given for the Mindoka Reclamation Project, Idaho.

Five excavators were in service on the project. Two steam dragline machines were started in 1910 and 1911. A small suction dredge was started in the spring of 1913 and two electric dragline excavators were started in Sept., 1913.

Steam Machines. The steam dragline machines were of the ordinary standard type and were built on the project. They have revolving frames, rope-swing, 1-yd. bucket and a reach from the center bearing to the end of the boom of 58 ft. The machine was mounted on rollers supported on planks. The approximate cost of the machine was $5,000.

The suction dredge was also built on the project. It consisted of a boiler and an engine direct-connected to an 8-in. centrifugal sand pump, mounted on a 10 x 30-ft. scow. The 40-ft. discharge pipe was counterbalanced by a weight suspended from a pole on the opposite side of the boat. The material was discharged back of a levee built along the line of the proposed construction. The

end of the suction pipe was kept on the center line of the drain, for by digging from 1 to 1½ ft. below grade the sandy soils slough in to approximate 1½:1 slopes and have the required bottom width. The machine was moved forward or backward and held in position by means of light cable controlled by drums operated by hand. The total cost of the machine was approximately $2,500.

Electric Machines. The two electric dragline outfits were Model 9½ Bucyrus machines, of the most modern type, having gear swing and caterpillar traction. The total reach of the machine when the boom is in digging position is 54 ft. The bucket is of 1¼-cu. yd. capacity, made by the Page Engineering Company. It is like the buckets used on the steam machines except that it has a chain in place of a stiff bail.

The caterpillar feature was a decided advantage as compared to rollers and greased skids. The data secured since the machines started show a saving of 5% of the digging time, besides eliminating the services of at least one man. The desirable features of the caterpillar are that the machine can be propelled in either direction, will go over very soft or rough ground, and may be turned in the length of the machine. The cost of each machine complete was approximately $13,800.

Cost of Excavation. The cost of moving 675,000 cu. yd. with the two steam machines averaged 13.22 ct. This cost was for work done on two different drains. Although each machine moved about the same amount of material, they worked under entirely different conditions, resulting in an average for one machine of 11.06 ct., and the other 15.13 ct. The detailed cost of the average yardage for the two machines per cubic yard of cross-section yardage is shown in Table 1.

TABLE I. UNIT COSTS WITH THE TWO STEAM MACHINES

Labor excavation	$0.0434
Hauling and pumping water	0.0123
Hauling and handling coal	0.0066
Coal, including freight	0.0252
Repairs, labor	0.0017
Repairs, material	0.0051
Cables	0.0034
Carbide	0.0013
Miscellaneous supplies	0.0049
Depreciation in machinery	0.0111
Engineering and administration (15%)	0.0172
Total per cu. yd.	$0.1322

In order to compare the cost of the steam and electrically operated machines, the lower cost, or 11.06 ct., will be used. The details are presented in Table 2.

TABLE II. LOWER UNIT COST FOR STEAM MACHINES

Labor excavation	$0.0360
Hauling and pumping water	0.0102
Hauling and handling coal	0.0048
Coal, including freight	0.0212
Repairs labor	0.0015
Repairs material	0.0037
Cables	0.0027
Carbide	0.0010
Miscellaneous supplies	0.0040
Depreciation on machinery	0.0112
Engineering and administration (15%)	0.0143
Total per cu. yd.	$0.1106

The average cost for the first two months' operation of the two electric machines was 7.1 ct. Even though the operators were inexperienced at first with this type of machine, and the conditions were slightly more difficult, a saving of 36% has resulted, the comparison being made on the total cost, which includes depreciation and engineering and administration. Aside from engineering and administration and depreciation, a comparison of the costs shows a saving of 56% in favor of the electric machines. The details are shown in Table 3.

TABLE III. UNIT COSTS FOR TWO ELECTRIC MACHINES

Labor excavation	$0.0204
Electricity, at 1 ct. per kw.	0.0045
Repairs, labor	0.0001
Repairs, material	0.0004
Steel rope	0.0011
Transmission line, at 6 ct. per ft.	0.0078
Miscellaneous supplies	0.0035
Depreciation on machinery	0.0240
Engineering and administration (15%)	0.0092
Total per cu. yd.	$0.0710

Table 4 shows a comparison of the detailed cost in a condensed form.

TABLE IV. COMPARISON OF COSTS FOR STEAM AND ELECTRIC MACHINES

	Steam machine	Electric machine	Saving
Labor	$0.036	$0.0204	$0.0156
Power	0.0372	0.0123	0.0249
Miscellaneous	0.0119	0.0051	0.0068
Depreciation	0.0112	0.0240	......
Engineering	0.0143	0.0092	......
Totals	$0.1106	$0.0710	$0.0483

Depreciation and engineering and administration are based on costs and yardages. Further, the steam machine has depreciation

figured at 1 ct. per cu. yd. and the electric at 2 ct., and, therefore, these items cannot be compared on the two machines.

The average amount of electric power per cubic yard of cross-section yardage has been 0.45 kw. since the two machines started. The average amount of coal per cubic yard of actual yardage was 7.4 lb., or 8.1 lb. for the cross-section yardage. When working under exceptionally good conditions in easy digging the pounds of coal per cubic yard should not exceed four; yet, this depends largely on the size of the boiler. Before the boilers on the steam machines were replaced with others of 35% greater capacity, the average amount of coal per cubic yard was 10 lb. From this will be seen at a glance the importance of large boiler capacity.

Transmission Line and Suction Dredge. The cost for electric line construction was $875 a mile.

The detailed costs on the suction dredge per cubic yard of cross-section yardage on 100,000 cu. yd. to Nov., 1913, are given in Table 5.

TABLE V. UNIT COSTS FOR SUCTION DREDGE

Labor excavation	$0.0567
Hauling and handling coal	0.0040
Coal, including freight	0.0161
Repairs, labor	0.0027
Repairs, material	0.0030
Cables	0.0004
Carbide	0.0007
Levee construction	0.0086
Miscellaneous supplies	0.0062
Depreciation on machinery	0.0200
Engineering and administration	0.0178
Total per cu. yd.	$0.1362

In addition to keeping detail cost per cubic yard of the different machines, a record is also kept of machine efficiency, which shows the percentage of digging time and various delays, such as moving, repairs, coating, etc. The actual yardage, as well as the cross-section yardage, is also computed in order to determine the percentage of excess yardage, and in this way hold the operators nearer the required section.

Cost of Stripping Coal Beds with Electric Dragline. *Engineering and Contracting*, June 19, 1918, gives the following:

Electrically-driven dragline excavators were used for stripping coal beds for the Locust Mountain Coal Co. at Shenandoah, Pa.

The stripping is done from 14 to 30 ft. deep. The rock encountered in the stripping process is drilled by steam drills and shot. In one position with this dragline it is possible to take a cut of 150 ft. wide. The excavator is placed directly over the vein and is followed by a steam or electric shovel.

With electric control of a dragline no fireman is needed, no coal passer and no pipeman. Further, there is no water pipe to freeze up and on the coldest mornings no delay is necessary to start the stripping operation, it being merely necessary to close the main line switch and start operation. The only labor which is required for the operation of this machine is the dragline operator, an oiler and a few men in the pit.

The dragline excavator has a 24-ft. diameter turntable, a 150-hp. hoist motor and a 75-hp. swing motor. The turntable consists of 40 open-hearth steel rollers revolving between two 90-lb. rail circles, 24 ft. in diameter, one attached to the bottom of the revolving frame and one to the top of the base.

The main machinery is driven by a direct-geared 150-hp. 440-volt Westinghouse slip ring type motor, operating at a speed of 565 r.p.m. and includes two drums, one of which winds the rope by means of which the bucket is dragged through the dirt and the other operates the rope by means of which the bucket is hoisted. There is also a small drum for the purpose of manipulating the rope by means of which the boom is lowered and raised.

The swinging machinery is operated by a 75-hp., 440-volt slip ring motor, driving a vertical swinging shaft by means of three gear reductions. A pinion on the vertical shaft engages the swinging rack on the base. The bucket used had a capacity of 3½ cu. yd.

Below is given the cost of stripping 256,710 cu. yd. during the year of 1915. It will be noted that the net cost is 4.23 ct. per cubic yard.

Classification	Labor	Material
Excavator crew	$1,463.50	$ 82.26
Pitmen	1,697.80	5.16
Blasters	107.02	1,804.22
Repair and maintenance	317.08	1,274.89
Electric repairs and maintenance	318.64	16.24
Transmission lines	74.56	7.60
Power		2,038.26
Foreman	339.16	2.25
Clerk	40.50	
Hauling	36.73	
Miscellaneous	1,664.13	13.00
Total	$6,059.12	$5,243.88
Credit to labor account for other work	427.25	
Net cost of labor	$5,631.87	
Materials	5,243.88	
Total net cost	$10,875.75	
Net cost per cu. yd.	$0.042	
Cost of power per cu. yd.	$0.008	

Bibliography. "Excavating Machinery," A. B. McDaniel. "Cost Data," H. P. Gillette." "Irrigation Works Constructed by the United States Government," Arthur P. Davis.

"Excavating Muskeg Bogs on Winnipeg Aqueduct," *Engineering News-Record*, April 19, 1917. "New Self Propelling Dragline Excavator," *Engineering and Contracting*, July 19, 1916.

CHAPTER XV

METHODS AND COST OF DREDGING

Dredges. The term "dredge" is loosely applied. In this book it will be taken to include only machines that float and are used for excavating under water. Of these there are four principal types, (1) The bucket or grapple dredge consisting of a crane mounted on a barge and equipped with a grab-bucket (orange-peel or clam-shell), or more rarely with a scraper bucket. (2) The dipper or steam shovel dredge, a floating steam shovel evolved from the original spoon dredge. (3) The elevator or ladder dredge, which is fitted with a bucket conveyor. This type is called bucket dredge by the English. (4) The hydraulic or suction dredge which excavates material by pumping.

Dredges may also be classified by references to the limitations under which they work, as for instance sea-going dredges, deep-water dredges, canal-dredges, etc.

"Land Dredges" are discussed in Chap. XVII.

Dredges may place the material they excavate directly on the bank, or load it into scows, or they may be provided with hoppers and carry their material to sea. The sea-going hopper dredge, used in large harbors where the water is too rough for scows, is usually of the ladder type, but suction dredges are also used for this purpose.

The hulls of dredges were formerly constructed of wood, but the use of steel for this purpose is gradually increasing.

Capacities of Dredges. The comparative capacity of dredges of various types depends upon many factors, such as the size and model of the dredge, the method of operating it, the character of the material to be excavated, the method of disposal and the many local conditions that may affect any one piece of work. It is therefore impossible to state with precision the output of a given type of dredge unless the conditioning factors are known. Mr. Charles Evan Fowler, in his book "Subaqueous Foundations," gives the capacity of dredges of various types, Table I. He states that this table has been compiled as a matter of judgment from experience gained through many years of construction and the operation of all kinds of dredges. The distances for towing the material and discharging it ashore are approximate. The capacity is that of a 24-hr. operation with 2 shifts.

Cost of Dredge Construction. The cost of constructing a dredge in California is given by Robert E. Cranston in a paper published in the *Journal of the American Society of Mechanical Engineers* for February, 1912. The following is an abstract of this paper appearing in *Engineering and Contracting*, Mar. 13, 1912:

TABLE I. CAPACITY OF DREDGES OF DIFFERENT TYPES

	Mud	Mud and sand	Light sand	Heavy sand	Sand and gravel	Heavy gravel	Stiff clay
Clamshell	2 miles	2¼ miles	2½ miles	3 miles	3 miles	4 miles	6 miles
2½ yd.	2,000 yd.	1,500 yd.	1,200 yd.	600 yd.	350 yd.	350 yd.	250 yd.
Dipper	2 miles	2½ miles	2½ miles	3 miles	4 miles	5 miles	5 miles
3 yd.	3,000 yd.	2,400 yd.	2,400 yd.	1,800 yd.	1,500 yd.	1,200 yd.	1,000 yd.
Dipper	3 miles	3 miles	3½ miles	4 miles	6 miles	8 miles	8 miles
6 yd.	5,000 yd.	5,000 yd.	4,500 yd.	3,500 yd.	2,500 yd.	2,000 yd.	1,800 yd.
Ladder				5 miles	5 miles	6 miles	8 miles
Dredge				2,500 yd.	2,500 yd.	2,000 yd.	1,500 yd.
Suction	6,000 ft.	5,280 ft.	5,000 ft.	3,000 ft.	2,000 ft.	800 ft.	1,000 ft.
20 in.	20,000 yd.	4,000 yd.	2,000 yd.	2,500 yd.	1,000 yd.	600 yd.	1,000 yd.
Suction	6,000 ft.	5,280 ft.	5,000 ft.	3,000 ft.	2,000 ft.	1,200 ft.	1,200 ft.
30 in.	30,000 yd.	8,000 yd.	4,000 yd.	5,500 yd.	2,200 yd.	800 yd.	2,000 yd.

Capacity in cubic yards per day, maximum tow in miles and length of pipe line in feet.
Clam-shell dredge, 2,250 yd. scows, 50 hp. tug.
Dipper dredge 3 yd. 3,300 yd. scows, 75 hp. tug.
Dipper dredge 6 yd. 3,500 yd. scows, 125 hp. tug.
Ladder dredge 3,500 yd. scows, 125 hp. tug.

For all the machinery, including motors, pumps, wire rope, electrical supplies, etc., 12½ ct. per lb. delivered on the ground; for installing, 4½ ct. per lb., or a total of 17 ct. per lb. for the machinery installed. The lumber costs about $30 per 1,000 ft. B. M. at Portland, and this, together with freight, bolts, nails, hog rods, steel plates, oakum, paint, etc., will make the hull material cost about $50 per 1,000 ft. of lumber used; labor of building costs about $40 per 1,000 ft., giving $90 per 1,000 ft. as a total cost of the completed hull. In addition the direct costs chargeable to hull or machinery, insurance, traveling, superintendence, camp equipment, temporary buildings, shop, derrick, office expense, design, etc., amount to between $10,000 and $25,000, depending on whether new designs have to be gotten out, what construction tools and equipment are on hand, the size of the dredge, and situation of the ground on which it is to be built. For a complete dredge, $180 per ton, on a basis of its displacement, is a fair average.

Selecting a Dredge. *Engineering Record*, Dec. 16, 1916, prints an article by Arthur M. Shaw, which is here given.

In approaching a dredging job of any magnitude the first and most important problem which confronts the contractor is the selection of the most suitable equipment. The best guide in the selection of equipment is found in records of past performances, though it should be kept in mind that good results have been secured in individual instances by nearly every type of machine now being sold. Certain well-developed types of dredges will work economically under a considerable range of conditions, but there is no one machine which is best suited to all, or even to most conditions.

This discussion of various types of equipment and the power plants used to operate them is confined principally to those used in the reclamation of lands in the lower Mississippi delta. The types considered are dipper dredges, orange-peel and clam-shell dredges, hydraulic dredges and drag-line dredges.

Dipper Dredges. Dipper dredges may be mounted on scows or may be operated on land. In the latter case they are supported on car wheels, with short sections of portable track, on broad-tread wheels for running on planks or on hard ground, on rollers for moving on planks, or on caterpillar treads, or are rigged as "walking dredges." Wherever it is practicable to secure sufficient water the floating dredge is usually preferred, as the expense and delays incident to moving ahead as the work progresses are reduced to a minimum with this type. On isolated work, requiring frequent tearing down and rebuilding of a floater, the land outfit is preferred.

Tearing down and rebuilding a floating dredge is a tedious and expensive operation. The salvage from an ordinary wooden hull is usually a negligible (and frequently a minus) quantity. Some of the new types of steel hulls, built in sections, have met these objections in an ingenious manner and should materially increase the field of operations of floating dredges. In a number of cases moderately large dredges have been moved intact over considerable distances across land, but the writer has yet to learn of any individual owner who has made such an experiment and who is ready to attempt it a second time.

Vertical and Bank Spuds Compared. The greatest variation in the details of floating dipper dredges is found in the types of spuds used, in the manner of raising and lowering the spuds and in "pinning up." There are two general types in common use — the vertical and the bank spuds. Vertical spuds are comparatively simple, are adaptable to a wide range of depth and are independent of the width of canal. They are usually raised and lowered by independent engines, either by means of cables or by compound gears engaging a heavy rack which is attached to the spud. Cables are now quite generally preferred, though the rack is still in common use and is preferred by some. Neither type has any marked advantage in the matter of simplicity. The cable system has one considerable advantage in that it permits setting the engines farther aft, where they can be more easily attended to by those having the care of the main engines.

The power for raising spuds on some dredges is compounded by means of worm gears, but the writer considers a worm gear a necessary evil, to be tolerated on some machines but never on a dredge.

Bank spuds give greater stability to the hull, being, as their name implies, set out on the berm or bank. They permit the use of a much longer boom on a dredge of given width than is possible by the use of vertical spuds. On some machines the bank spuds act as an outboard support, the strain being carried to the hull by a well-braced structure acting as a beam. In other cases the strain is transferred direct to the top of the A-frame. That portion of the spud which rests on the bank is in the form of a plank platform, and for work in soft material these platforms are extended so as to cover a considerable area. In some cases these platforms are hinged along the center so that they may be more easily raised out of sticky material. One of the principal objections to bank spuds is that they often crush down the berm, inducing slides in the levee or waste bank. It is impracticable to use bank spuds in wide canals or open water of any considerable depth.

Owing to the powerful thrust of the dipper acting in various directions, the rigid bracing of spuds and fastening of all spud connections, whether of the vertical or bank type, are most important.

Dipper Dredge Best for Hard Digging. Comparison with other types of dredges is most favorable to the dipper type when working in hard, compact material such as cemented gravel and ledge rock. It is usually preferred for digging through heavily timbered country, especially through trees having large tap roots. Its ability to bring a tremendous amount of power to bear at a single point contributes to its popularity in heavy timber work. Whenever possible, however, all large stumps should be loosened and shattered before the dredge reaches them.

Hard gravel and rock should be blasted ahead of the dredge even though it may be possible to make some progress without first loosening the material. Dipper dredges equipped with crowding engines on the boom and with special teeth on the bucket will make fair progress without preliminary blasting in soft limestone rock which is in fairly thin layers. It will usually be found more economical, however, to do some preliminary blasting in all such material.

Loss of time frequently occurs in the use of a dipper dredge by the jamming into the bucket of a large stump or boulder, though a skillful operator will seldom permit this to occur.

In mucky soils dipper dredges often disintegrate the material to such an extent that much of it is carried in suspension in the canal for several hours, to be deposited later in the bed of the canal and materially reduce the section. In the very soft trembling prairies of southern Louisiana this will occur to a certain extent with any type of dredge, but is most noticeable with dipper and dragline machines, which require a long movement of the bucket in filling.

Grab-Bucket Dredges. Variations in mounting and methods of moving are much the same with grab-bucket dredges as with the dipper type. Spuds are usually cable-operated. The spuds are used as anchors only, since there is less necessity for pinning up a dredge with this class of machinery. For levee construction and other classes of work on which the bulk of the material is to be dumped to one side of the excavation, gravity swing out 'ts are preferred on account of their simplicity, low first cost and economy of operation.

Orange-peel and chamshell buckets are most efficient in handling gravel, sand and soft material, though boulders, pig iron and blasted ledge rock are handled economically by the larger, three-bladed orange-peels of extra-heavy construction. In hard, packed

sand the clamshell is most suitable, as it gathers its load by the scraping action of the blades. In hard digging teeth are placed on the edges of clamshell buckets for loosening the material. Though, owing to the large number of wearing parts, repairs are frequently required with grab buckets, they are readily made, usually by the substitution of small bushings and pins. A liberal supply of these repair parts should be kept in stock. It is usually found most economical to keep an extra bucket on hand so that at least one may be in perfect condition at all times.

Orange-peel buckets are preferred to clamshells for digging stumps, widening canals and other work where it is necessary for the bucket to fill on irregular surfaces or grab hold of materials of varying density. For digging stumps other than those having large tap roots the orange-peel dredge of large size is fully equal to any other type. Its ability to dig on all sides of a stump, tearing loose each individual main root, makes up for its lack of the great lifting and shoving power of the dipper dredge.

While not well adapted to digging hard sand, the orange-peel bucket may be used in such material with moderate success if properly handled. To insure economical loading the bucket should be dropped into the pit in a partly closed position, the blades being held as nearly vertical as practicable. After dropping, the closing line should be overhauled slightly and released, repeating this operation as many times as may be necessary to load the bucket. It is not usually feasible to secure a full load by this method, nor is this desirable, as the "suction" in such material is so great that it is almost impossible to break loose with a full bucket of packed sand.

Though careless manipulation of dredges of any type when working in soft muck will stir up the material in much the same manner as will a dipper dredge, grab buckets, if intelligently handled, will excavate such material much better than any other bucket dredge. When working in material easily carried in suspension by the water, the bucket should not be permitted to bury itself in the bottom of the canal, but should be held by the "standing line," so that it will load with only such material as it can take out of the canal. Overloading and consequent dropping of broken material back into the water is the cause of most of the loss in section through sedimentation of canals dug by grab buckets. In cleaning out old canals which have become partly filled with fine ooze especial care is necessary to insure tight closing of the bucket. In the tough muck and Sharkey clay which are typical of the lower Mississippi delta grab buckets may be loaded 30 to 40% beyond their rated capacity without danger of any considerable portion of the load dropping off.

Grab-Bucket Dredge Could Build Levees. Until quite recently most of the river levees on the lower Mississippi were built by wheelbarrow or team work. These methods are now largely superseded by land dredges and by tower and cable rigs, though a few floating dredges are also used. As the material for building these levees is taken from the river side and land equipment cannot be operated excepting during moderately low stages of the river, the working period is reduced to a few months of each year. It would seem as if, by making a slight modification in the specifications for the construction of these levees, it would be possible to use floating dredges with extra-long booms for a large portion of such work.

Hydraulic Dredges Preferred for Filling Low Land. Hydraulic dredges are often preferred for interior canal construction on account of their ability to spread the excavated material over a wide area, thus avoiding wasteful and unsightly banks. The preferred method in cutting new canals is to make a first cut with a small bucket dredge, dumping the material in about equal quantities on each side, to form a barrier which prevents the material excavated by the hydraulic dredge from flowing back into the canal. In other cases a small hand-built levee serves the same purpose. A levee or ridge of sod 2 ft. in height will usually retain the discharge from a 12-in. hydraulic dredge, provided the point of discharge is 30 ft. or more beyond the levee. For canals having a cross-section much in excess of 10. cu. yd. per lin. ft., a larger levee will be required.

Suction dredges are subject to delays through the stoppage of suction pipes and pumps from grass roots and other débris. The larger sizes are seldom troubled by anything smaller than stumps. Nothing less than a 10-in. pump should be used for work of this class owing to frequent stoppages of the suction line. Very large sizes are unsuitable because they require hulls of too large a size for small canals. A 12-in. dredging pump with all necessary equipment can be mounted on a barge 24 x 80 ft. which will be found suitable for digging 30 ft. canals.

Types of Cutter Heads. Rotary cutter heads are used on the suction line from the pump, their design and speed of rotation being dictated by the character of the material excavated. In hard, gravelly material a rugged cutter head is required which will produce the maximum agitation of the material. In the muck and soft clay soils of the lower Mississippi delta a slicing action of the blades secures better results, especially if combined with only moderate speed of rotation.

For the excavation of narrow canals a ladder is required which is flexible in all directions, as the space is too limited for keep-

ing the intake to its work by swinging the hull. The swinging device should be subject to the easy control of the operator in order that the greatest economy of operation may be assured. The effective work of a hydraulic dredge depends to a great extent on the percentage of solids discharged. This percentage will drop if the dredge is operated carelessly, or if it is not equipped so that the cutter-head may be kept close up to the work and so regulated that it will not clog.

Power.— Heretofore steam power has been used almost exclusively the smaller dredges being equipped with the simplest type of slide-valve hoisting engines. Hydraulic dredges have usually employed a better grade of engine in their main power unit.

Great difficulty is experienced near the coast in securing suitable boiler-feed water. The unlimited use of raw water from the canals results in expensive delays and repair bills through the rapid deterioration of boilers, steam piping and engines. This trouble is reduced, though not eliminated, by the use of condensers. A dredge equipped with a complete salt-water outfit, including condenser, circulating and vacuum pump and a high-speed evaporator, was constructed by the writer in one instance for use in waters which were exceptionally bad. This plant has now been in nearly continuous operation for three years with no serious delays from the steam end of the outfit. Although the steam auxiliaries cost nearly the same as the boiler itself, it appears by comparing the operation of this dredge with that of others operating in the same water, but not similarly equipped, that the extra equipment has paid for itself several times over.

The intermittent but frequently excessive demands for steam on most types of dredges makes it necessary that an ample capacity for producing dry steam should be provided. Condensers, evaporators and steam separators are an aid, but nothing will fully make up for a deficiency in boiler capacity. Foaming, due to overcrowding the boilers, especially when supplied with poor water, reduces the available power of engines, carries away the lubrication and contributes to a large extent to engine breakdowns.

Short Stacks a Disadvantage. Another factor in limiting the power supply is curtailment of draft through the unnecessary abbreviation of the stack. There is no reason why the average floating dredge should not carry a smokestack more nearly approximating the length established as good practice in other lines of steam engineering. In spite of this fact it is not uncommon to see an 80 or 100-hp. dredge boiler supplied with a 20-ft. stack. The design of the stack, however, should be based on the coal burned per hr. rather than on the rated horsepower of the boiler,

which should be considerably in excess of the theoretical requirements.

American and European Practice Compared with Regard to Dredging. The practice in America and Europe differs considerably. In Europe permanent plants are constructed for the gradual execution of large projects and this makes it economical to plan work along the ultimately cheapest line, and to construct high priced plants for doing the best work in the most efficient manner. On the other hand, in America the ordinary short-time contract of small size compels the contractor to build the cheapest plant that will do the particular piece of work in hand. However, this condition in America is rapidly changing, the increased size of ocean vessels and the expansion of commerce demanding larger and deeper channels and better harbor facilities. A number of large and powerful dredges have been built in the last decade.

Government Dredging vs. Contract Dredging. *Engineering News*, Apr. 2, 1914, gives the following:

Lieut.-Col. Harry Taylor, Corps of Engineers, U. S. A., Assistant to the Chief of Engineers, Washington, D. C., has compiled the following data in regard to the relative costs of dredging with government-owned plant and by contract, which are published in the *Professional Memoirs* of the Corps of Engineers for March–April, 1914. The data cover the fiscal year June, 1912, to June, 1913, and are essentially as follows:

(*a*) Government dredges excavated during the year a total of 52,564,497 cu. yd. at an average rate of 7.2 ct. per cu. yd. This amount of material was divided between the different classes of government dredges as follows: Hydraulic pipe-line dredges, 21,351,780 cu. yd. at a cost of 6.4 ct. per cu. yd.; by seagoing dredges, 27,502,996 cu. yd. at a cost of 6.14 ct. per cu. yd.; by dipper and bucket dredges, 3,709,721 cu. yd. at a cost of 19.8 ct. per cu. yd.

(*b*) Dredging contracts completed during the year or in force at the end of the year, included a total excavation of 181,873,125 cu. yd. at an average rate of 14.4 ct. per cu. yd. This excavation was divided among different classes of dredges as follows: Hydraulic pipe-line dredges, 101,518,980 cu. yd. at a cost of 10.16 ct. per cu. yd.; by dipper and bucket dredges, 80,354,145 cu. yd. at a cost of 19.8 ct. per cu. yd.

In the cost of dredging by government plant there is included all expenses for operation, ordinary and extraordinary repairs, surveys, and such office expenses as are chargeable to dredging operations, while the cost of the contract dredging is the contract cost only, and does not include the cost of government inspection,

surveys, office expenses, etc., that are charged against the government plant.

The government dredging plant comprises 22 seagoing dredges, 54 hydraulic dredges, 40 dipper dredges, 22 bucket dredges and the necessary equipment of tugs, scows, pontoons, barges, etc., representing a total investment of $12,583,563. Lieut.-Col. Taylor concludes that the saving in cost had the government dredged the 181,873,125 cu. yd., which were let by contract, would have paid for all the dredging equipment at present owned by the government.

[These figures are not to be taken too seriously. They do not show the comparative sizes of government and contract jobs. Moreover, interest and depreciation (exclusive of repairs) on the government's investment are not stated and may not be included. It is probable that were the government to call for bids on large, long-time dredging contracts, the contract prices would be below the total costs with government dredges.—The Author.]

Combined Grab-Bucket and Dragline Dredges. A locomotive crane or hoisting engine and derrick mounted on a scow makes a serviceable grab-bucket dredge, and, if properly designed, may also be used as a dragline excavator (Fig. 1).

(This same crane also is used with a dragline bucket.)

Stone Grapplers. These are specially designed grab-buckets for use in lifting rocks and boulders from the bottom of rivers, for ripping out crib work and for pulling stumps from streams. Sizes of from 1 to 10 cu. yd. are available.

Proportions of Orange-Peel Dredge. The following table illustrates the ideas of Arthur M. Shaw, previously quoted, as to suitable proportions for a 1½-yd. orange-peel, gravity-swing dredge designed for a given reach of 50 ft. from the side of the excavation. These proportions contemplate setting the machinery down in the hull.

Width of hull	36 ft.
Length of hull	80 ft.
Depth of hull	6 ft.
Length of boom	75 ft.
Spread of main drums	16 ft.
Double-cylinder main engine	10 x 12 in.
Boiler	80 hp.
Diameter of stack	27 in.
Height of stack	50 ft.

Clamshell Dredge with 195-ft. Boom. *Engineering News*, Mar. 1, 1917, describes a clamshell dredge with a 5-yd. bucket for use in building levees along California rivers. The boom is made up of three lengths, the outer section 20 by 22 in., and the other sections 22 x 22 in. The total length of the boom was 195 ft.

Fig. 1. Locomotive Crane Used on Scow as an Orange-Peel Dredge.

It is trussed vertically and laterally, long timber spreaders carrying the side truss rods. To take care of the list of the dredge when the boom swings out 90° from the center line, the A-frame cap is 5½ ft. forward of the pivot point of the lower end of the boom known as the heel casing. When the boom swings at right

Fig. 2. Stone Grappler for Use on Dredges. Made by Theodore Smith and Sons, Jersey City, New Jersey.

angles, the dredge has considerable list, and this offset permits the boom to swing around on practically a level plane. If the dredge is properly balanced, the righting of the dredge when the bucket is emptied will swing the boom back to center line. This makes rapid handling possible even with so long a boom, and gives an effective machine for building levees of material excavated in the stream.

A "Storage Drum" for Dredge Cable. *Engineering News*, Feb. 7, 1907, gives the following:

A cable drum of special design, invented and patented by W. S. Edwards, has an extension of about 800 ft. of cable in addition to the 200 ft. working length, so that a single cable 1,000 ft. long is carried. With the ordinary arrangement this dredge would have a hoisting cable about 180 ft. long, and when this is broken the entire cable would have to be thrown away. As the cable usually breaks at about 80 ft. from the outer end, the remainder is then too short for further use. With the Edward "storage drum" only about 80 or 90 ft. of the outer end of the cable is lost. The working length is restored by paying out sufficient cable from the storage part of the drum. Since cables of this kind cost about $2 per ft. (cables referred to are 2½ in. dipper cables) and they usually break in less than a month and sometimes in less than a week, averaging about 3 weeks in a season of 30 weeks, this cable storage system would effect a saving of $2,000.00 in cost of cable alone, for ten 100-ft. lengths of cable thrown away. In addition there would be a saving of about 3 hr. for each break or 30 hr. for the season. At $30 per. hr. this would mean $900. Contractors who have used this rig say that in actual use it has saved even more than that. The total saving of cable and time during one sesaon being about $3,000.

Cost of Clam-Shell Dredging at Oakland, Cal. The cost of dredging with clam-shell dredges at Oakland, Cal., is given by L. J. Le Conte in *Transactions, Institute Civil Engineers*, Vol. 89 (1887). These machines were unable to dig clean sand successfully and in hard material could do nothing. The plant employed comprised the following:

2 clam-shell dredges	$40,000
1 large tug boat	25,000
4 dump scows	20.000
2 water-boats	3.000
Total plant	$88,000

The loaded scows were towed one mile to the dumping ground. The depth excavated was 24 ft. The material was soft mud. The cost exclusive of interest, depreciation, insurance and taxes was as follows for two dredges operating over a period of 8 yr.:

Salary of employees	$210,962
Repairs	94,504
Coal	81,725
Ship chandlery and water	32,851
Miscellaneous, including docking dredges, tugs and scows	2,637
Total for 8 years	$422,679

Number of cu. yd. dredged	5,603,401
Number of hours worked	31,670
Cost per cu. yd., ct.	7.54

Vacuum Pump and Delivering Dredge. A dredging apparatus used at Far Rockaway, Long Island, N. Y., was described in *Engineering News*, June 13, 1895. The dredge consisted of a large rectangular hull with two derrick towers at the bow end, each one of which handled an orange-peel bucket. The equipment throughout the dredge was in duplicate. The material was dumped into hoppers or receivers from each of which a pipe led to the pumping apparatus. This apparatus was a Hussey pump practically on the same plan as the old Savary pump or modern pulsometer, the suction being obtained by means of a vacuum and the discharge through direct steam pressure. The plan of working was as follows: When the hopper was filled with sufficient material to fill the pump, a vacuum was created by a water supply condensing steam in a chamber, and the load was driven into the pump by the pressure of the outside air. Steam at 10 to 100-lb. pressure (according to the height of lift and the length of the discharge pipe) was then admitted. This forced the material through the shore delivery pipe. Both pumps discharged into the same pipe, thus keeping the column moving at a fairly constant rate. Both the Badger and Riker pumps worked on the same plan, but discharged the material into chutes.

At Rockaway the orange-peel buckets were from 4.5 to 6 cu. yd. in capacity. The hoisting engine had a cylinder 14 x 18 in.; the vacuum pump has a 28-in. cylinder; the steam pressure was 18 to 35 lb. per sq. in. The discharge pipe was 2,500 ft. long. With the pump making 1.5 to 2 strokes per min., in material consisting of 70% sand and gravel, and 30% mud, 500 cu. yd. per hr. were dredged. The apparatus handled large stones readily. The material, as delivered from the pipe, was 50% water and 50% solid matter.

On the Massena Canal a special designed dredge of somewhat similar type as the above described machine was used. This dredge was equipped with rotary cutters and disintegrating water jets. The material was dredged with 4-cu. yd. orange-peel buckets dumping into hoppers, and thence fed to centrifugal pumps. John Bogart, in *Engineering News*, Oct. 30, 1902, stated that these machines could handle the softer material, as a whole, but the vacuum method of transmission was a failure, the clay forming into balls in the hopper instead of remaining suspended in the water.

While clay will form into balls in centrifugal dredges it will pass through the pump and pipe line.

Cost in Clay with a Large Clam-Shell Dredge. The following is given by Emile Low in *Engineering News*, Oct. 11, 1906. The Buffalo breakwater was composed in part of a rubble mound resting on a sand foundation. This foundation was dumped from scows as soon as possible after a trench had been dredged to receive it. The natural material composing the bottom of the harbor was chiefly a moderately stiff red clay, mixed with some blue clay, the weight in general being about 3,300 lb. per cu. yd. Overlying the clay was a layer of sand 1 or 2 ft. thick, and underlying it, next to the bed rock, was a layer of hard, blue clay, mixed with broken stone or gravel, with boulders in places. The material was excavated from depths up to 70 ft.

The dredge built for excavating this trench was a 10-yd. clamshell dredge, operated by an 18 x 24-in. main engine, and two secondary 10 x 12-in. engines, supplied with steam from two boilers.

The dredged material was transported to the dumping ground, 10,000 ft. distant, in 1 hr. 6 min. Three steel scows, each holding an average of 400 cu. yd. were used.

During the season (from May 5 to Oct. 16, 1899), 316,343 cu. yd. scow measure, or 286,335 cu. yd. place measure, were dredged. This shows an increase of scow over place measure of 10.48%. The crew employed and their monthly wages were as follows:

1 runner	$90
1 second runner	35
1 fireman	35
1 deckhand	35
1 greaser	30
1 watchman	30
7 deckhands at $30	210
1 cook	30
1 cook's helper	15
Total monthly wages	$510

The work began at 5 A. M. and ended at 7 P. M. with 1 hr. out for two meals, leaving a net working day of 13 hr. For working overtime the men received 15 ct. per hr. Subsistence cost $12 per month per man. One-half the wages of the superintendent or $62.50 per month was charged to dredging. The cost of fuel was 0.55 ct. per cu. yd. dredged.

Pumping of dredges and scows was performed by a steam siphon rigged up on an old dredge. The cost per month was $40 for 1 man, plus $30 for 20 tons of coal at $1.50, a total of $70.

New steel cables cost $100 per month; oil, grease, waste, etc., $20; blacksmith shop, $175; hemp lines, cables, etc., $40; miscel-

laneous expenses, $50; yard expense, $100 per month. Range piles and buoys cost $256 for the season. Small tugs with coal, $20 per day; large tugs, coaled, $25; larger tugs, coaled, $30 per day.

The approximate value of the plant was as follows:

Clam-shell dredge	$60,000
3 steel dump scows	32,000
Total plant	$92,000

The annual depreciation at 10% amounted to $9,200, and the annual interest at 6% to $5,520, a total of $14,720.

The cost of the work during the season of 1899, was as follows for 316,343 cu. yd. scow measure.

	Per cu. yd.
Superintendence	$0.001
Wages	0.009
Board	0.003
Coal	0.005
Towing, tug hire	0.018
Syphoning	0.001
Cables, main, steel	0.002
Lines, ropes, etc., hemp	0.001
Blacksmith shop	0.003
Yard expenses	0.002
Miscellaneous expenses	0.001
Range piles and buoys	0.001
Total operating charges ($14,702)	$0.047
Depreciation and interest ($14,720)	0.046
Total cost ($29,422)	$0.093

The above does not include overhead expenses, dockage, heavy repairs and renewals, insurance, cost of getting to and from the work, preparatory expenses, etc. The contract price was 18 ct. per cu. yd.

During the five months of the season of 139 working days, 1,121 hr. were actually worked, and 801 hr. were lost on account of delays. During this period 952 scows, holding an average of 332.3 cu. yd. each, were loaded in the average time of 1.18 hr. per scow. The average number of hr. worked per day was 8; the average amount dredged per hr. worked was 282.1 cu. yd., and per day was 2,263 cu. yd. The maximum day's work was 5,037 cu. yd., and the maximum hr. work was 438 cu. yd.

The delays were as follows:

	Hrs.
Dredge: Repairs to cables, bucket, engines, boilers, frame and boom, general	140
Anchors and attachments	7
Scows: leaking, repairs, pumping, delays, tug delays	59
Rain, fog, sea	322

Moving and placing	68
Meals	125
Miscellaneous	37
Holidays	43
	801

Cost with Clamshell Dredges at Vicksburg. H. St. L. Copee gives the cost of dredging in Vicksburg harbor in 1888, in the discussion of a paper published in *Transactions American Society of Civil Engineers*, Vol. 31, 1894. The machine used was a clamshell dredge. The daily (2 shifts) cost of the work was as follows per 24 hr.:

16 laborers at $30 per month	$ 16.00
2 enginemen at $60 per month	4.00
2 captains at $125 per month	8.25
2 cooks at $45 per month	3.00
Dredge total	$ 31.25
6 men at $30 per month	$ 6.00
2 captains at $125 per month	8.25
2 cooks at $45 per month	3.00
2 engineers at $60 per month	4.00
Tug total	$ 21.25
Subsisting 36 men (including 2 inspectors) at 50 ct.	18.00
Coal for dredge and tug (6 tons)	25.00
Incidentals, repairs	10.00
	53.00
Total per 24-hr. day	$105.50

The average monthly output was 55,529 cu. yd. (scow measure) and the cost 5.5 ct. per cu. yd. This cost does not include interest or depreciation, or the cost of getting the dredge to the working locality. The depth of water was 35 ft. The material dredged was mud and silt. The dumping ground was 1½ miles distant.

Low Cost with an Orange-Peel Dredge. According to a letter of A. M. Shaw, *Engineering News*, Apr. 30, 1914, the following is the cost of operation of a 1½-cu. yd. orange-peel dredge during a run of 15¼ months.

Labor (double shift)	$ 6,458.64
Fuel	4,776.09
Main hoisting cables	1,011.04
Repairs and renewals (other than cables)	2,184.19
Lubricating oil	280.08
Miscellaneous supplies	357.36
General (includes board of crew and operation of gasoline tenders, etc.)	2,175.41
Estimated amount of supplies used in above time, but paid for by vouchers of following month (liberal estimate)	1,200.00
Total operating charge	$18,442.81

Miscellaneous and Overhead Expenses:	
Proportion of cost of running main office and engineering force.	$ 3,050.00
Interest on cost of dredge at 5%	1,080.00
Depreciation at 6%	1,300.00
Depreciation and interest on house boat, fuel barges and other auxiliaries	600.00
Insurance on dredge and auxiliaries	528.00
Total miscellaneous and overhead	$ 6,558.00
Total cost	$25,000.81
Total material excavated, cu. yd.	924,204
Cost per cu. yd.	$0.026

The material excavated was unusually well suited to the type of dredge used, being a light-weight muck over a soft clay. Occasional sand deposits were encountered, but these formed a very small percentage of the work. The kind of material accounts for the low cost. The measurements of material handled were taken in excavation. Operating charges were from actual cost records excepting the estimate shown on the last item. Wages were somewhat lower than those paid in most Northern states. Oil was used for fuel until the cost came to $1.25 per bbl. delivered, when coal was substituted, at a cost of about $4 per ton.

Dredge with Dragline Bucket. In 1904 a small dredge equipped with a derrick for handling a Page dragline scraper, was used to excavate compact glacial drift from under water, for filling a cofferdam at Green Lake, Wis. The material consisted of a light covering of sand overlying packed marl, clay, gravel and boulders. A centrifugal pump proved a complete failure, and an orange-peel bucket brought up only 30 lb. per trip. The scraper bucket handled 300 to 400 cu. yd. per day. The hull of the dredge was 42 x 28 x 2.5 ft. in size. The derrick had a 32-ft. mast and 95-ft. boom, both of 12 x 12-in. pine. The power equipment comprised two engines and a boiler.

Dipper Dredges. *Engineering News*, May 14, 1903, describes the dipper dredge as follows:

A dipper dredge is really a scow-mounted steam shovel. The machinery is usually of larger size than that used for work on land, the dipper handle being very long and the dipper ranging in size from 1/8 to 15 cu. yd. This type of machine is best for general purposes. Dipper dredges are comparatively cheap and simple in construction, can do harder and heavier work than the other types of dredges, and can deal with stumps, roots, and other obstructions. Hard compact material such as glacial drifts can be dug because of the positive application of the power to the penetration of the bucket. In fact this type of dredge is the only one capable of handling very hard material such as cemented gravel and large pieces of blasted rock.

The dipper dredge possesses one great advantage over the other

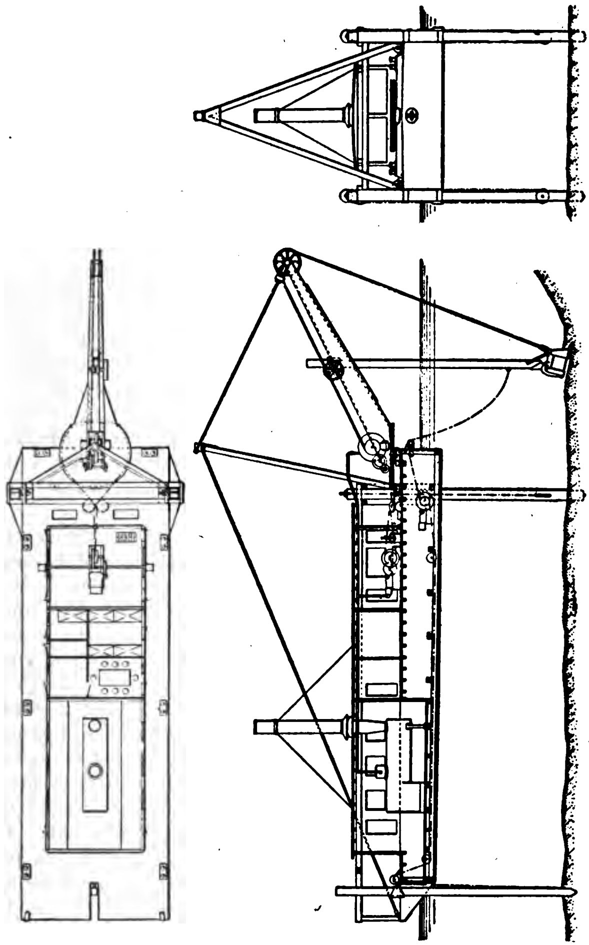


Fig. 3. 2½-yd. Dipper Dredge.

kinds because of its "spuds." Spuds are legs of heavy timber (or, sometimes, steel) which are raised and lowered vertically, and when sunk into the mud provide a firm anchorage for the hull. The boat can manœuvre on its spuds, using its dipper to pull itself into any desired position, and consequently it does not obstruct traffic with anchor lines. It can push its scows about with its dipper. While suited best to comparatively shallow depths it can dig equally well to the full reach of its dipper or can cut barely enough to enable it to float. By changing the size of the dipper it can be readily converted from a hard material machine to a soft material machine. This is a most important consideration to contractors. The entire machine is under the control of one leverman and the necessary crew of one operator, one cranesman, 2 or 3 deckhands and a fireman.

Dipper dredges were formerly of the crane type but are now usually of the boom type. The average size of dippers generally used is about 6 cu. yd. The largest dredge of which the writers know is the "Onondaga" which has a 15-cu. yd. dipper, a hull 140 x 50 x 15 ft. in size, and which can excavate to a depth of 50 ft.

The outputs of dipper dredges depend naturally upon many factors, chief of which are the size of the dredge, the depth being excavated, and the character of the material. On the Great Lakes a dredge equipped with 4.5 to 6-cu. yd. dipper excavated 4,450 cu. yd. in 10 hr. from depths of 20 ft. loading into scows.

Conditions Favorable to the Dipper Dredge. The dipper type of gold dredge is suited to conditions where the ground is somewhat shallow, where the extent of ground is not sufficient to warrant a costly dredge, where the material is of somewhat rough character containing boulders and stumps and where the ground contains adhesive clay which is difficult to remove from elevator dredge buckets.

Cost of a Dipper Dredge. The main dredge ditch of a swamp in Harney County, Oregon, was approximately 24 ft. wide and 8 ft. deep, with banks sloping at 1 to 1. The work was located far from railroads and mills, lumber having to be hauled 60 miles, and it was therefore necessary to design a machine the materials and machinery for which could be conveyed economically. The ground was generally swampy, the material being namely a peat soil on a peaty, loam or clay sub-soil with pockets of cobbles and gravel. The machine determined upon for the work was a dipper dredge with a 1¼-yd. dipper.

This dredge had a hull of lumber 19 x 75 x 6 ft. in size. The boiler was a 50-hp. locomotive type boiler, and there were 2 engines, 10 x 12 in. in size, for operating the crane, and 7 small auxiliary engines for hoisting spuds, etc. The largest single

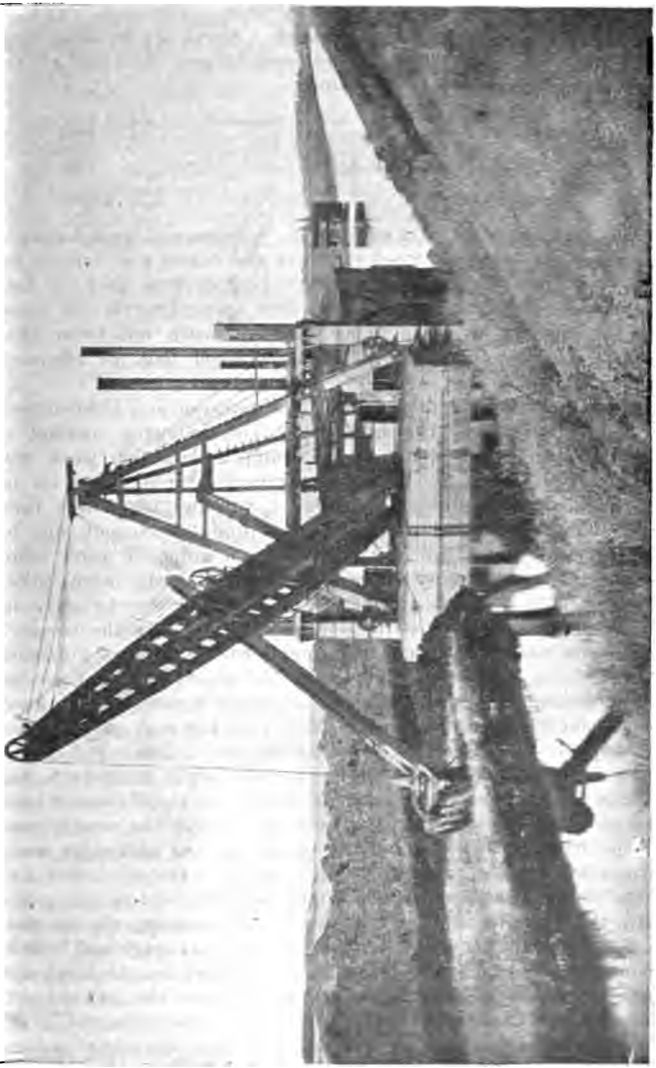


Fig. 4. 3-cu. yd. Dipper Dredge, Made by the Marion Dredge Co., on Drainage Work in S. D.

piece was the boiler which weighed 7,000 lb. The crane was handled in three parts of 2.67 tons each. About 2½ months' time was required to construct the hull and barges. The cost of the plant was approximately as follows:

Machinery and hull	$ 9,750
Quarter-boat, 2 wooden scows, etc.	4,900
Freight	2,100
Hauling	1,200
Total cost of plant	$17,950

The crew consisted of 1 engineman, 1 fireman, 2 deck hands, 1 cook and the necessary wood choppers and teams and drivers for supplying fuel. Sagebrush and dwarf juniper were used for fuel. The costs of obtaining both woods were approximately the same, but the labor required in firing the sage brush was twice that necessary for the juniper. The latter wood had an efficiency greater than that of pine.

Aligning a Dredge in a Canal. *Engineering and Contracting*, Feb. 13, 1907, gives the following: The following method of aligning a dipper dredge used in swamp reclamation work was employed with success. A permanent back-sight flag was set on the starboard water edge of the canal, and two permanent fore-sight flags were set at the end of the proposed tangent, one on the right and the other on the left of the proposed water edge. Two 3 x 12 in. planks extending out from the dredge were spiked to the port and star-board gunwales of the dredge to serve as gages. These planks were located directly opposite the runner's levers and were placed at right angles to the axis of the scow. A series of numbers was painted on the gages, the numbers being so arranged that the distance from any number on the starboard gage to the corresponding number on the port gage equaled the required width of the canal at the water line. Before the day's dredging commences, the runner sets up a temporary flag back of the starboard gage, and in range with the starboard back and fore-sights. After each move of the dredge the runner goes out on the starboard gage until he comes into the back-sight range formed by the temporary flag. He then faces the other way and spots some natural object upon the forward cutting, in range with the forward starboard sight. After noticing the number that he is standing upon, he goes to the port gage and stands upon the number corresponding to the number on the starboard gage. After selecting some natural object upon the forward cutting range with the forward port sight he returns to the levers and cuts to these natural objects.

Erection Costs of Steel Knock-Down Dredge. *Engineering News*, July 6, 1916, gives the following:

A new design of steel dredge was recently brought out by the American Steel Dredge Co., of Fort Wayne, Ind. It is of the single-line type. The improvements pertain to the so-called structural part of the dredge or the front end, embodying the dipper, dipper handle, boom and circle. Dippers in general use are of the square type, but the one on this dredge is made with an exceptionally wide mouth and narrow back. The shell is formed of one piece of flanged steel riveted to the back casting, with a flanged-steel mouthpiece and lower band.

The design of the dipper handle is unique and opens another field for acetylene welding. Dipper handles in common use are

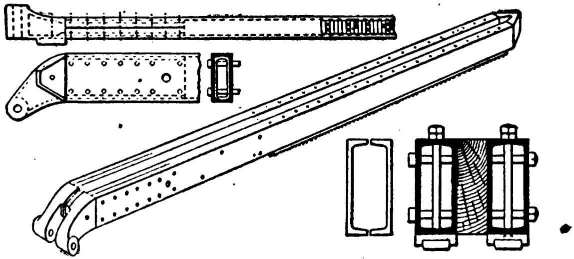


Fig. 5. Dipper Handle Formed of Two Rivetless Steel Boxes.

of wood or of wood armored with steel plates on the four sides or are made of steel. In the latter instance they are usually built of I-beams reinforced to form a box section. The construction of the new handle is a hollow-steel box section devoid of rivets. The box is formed by coping the flanges of two channels, so that when the latter are placed together they form a section of the proper width. The flanges are then welded for the entire length on both edges. Two of these box sections are required for each handle. The racks are bolted on in the same manner as on a wooden handle. The dipper-handle foot casting is put in place before the channels are welded, so that when this is done the channels contract, resulting in a tight fit on the casting.

The dredge has a sectional hull, built entirely of flat steel sections of convenient sizes for easy handling. A complete hull 80 x 20 ft. in plan by 6 ft. deep can be loaded on one flat-car. The tabulation that follows gives the cost of transporting and erecting one of the new machines. The figures were furnished the manufacturer by the contractor and are for one of the new dredges, equipped with a 1½-yd. dipper and 50-ft. boom, used on a large drainage district in Arkansas.

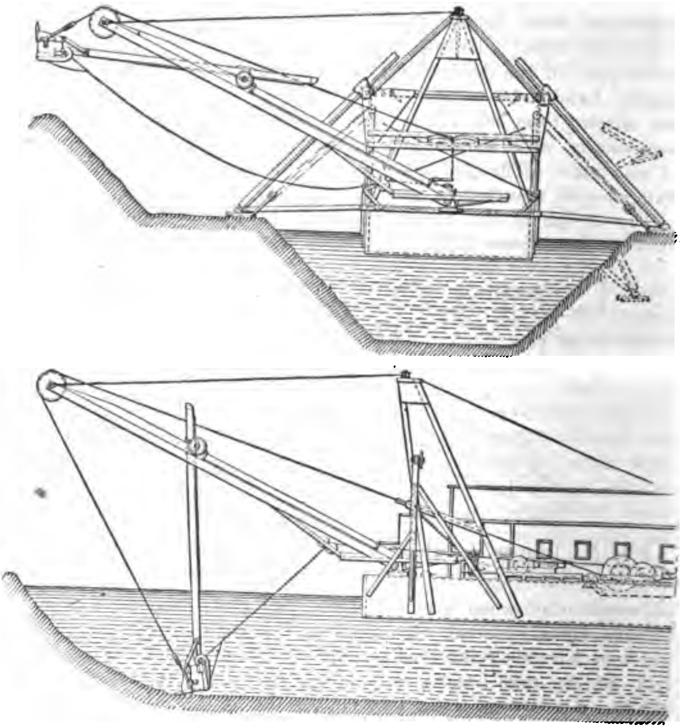


Fig. 6. "American" Steel Dredge with Bank Spuds.

Transporting Steel Hull

Hull, weighing 88,000 lb., arrived on job. Oct. 22; hauled to bank on Oct. 23 and 24	
60 man-hours @ 20 ct.	$ 12.00
110 man-hours @ 17½ ct.	19.25
20 hours for foreman	8.80
Two days' teaming	19.00
Total transporting hull	$ 59.05

Erecting and Launching the Hull

Erection began Oct. 26; completed Nov. 4 (work delayed 1½ days by hull grounding)	
275 man-hours @ 20 ct.	$ 55.00
424 man-hours @ 17½ ct.	74.20
90 man-hours @ 12½ ct.	11.25
Total erecting hull	$140.45

Hauling Machinery

Machinery arrived on two cars Oct. 29; hauled to dredge Oct. 30 to Nov. 4

50 man-hours @ 20 ct.	$ 10.00
110 man-hours @ 17 ct.	18.70
30 hours for foreman	13.20
Total hauling machinery	$ 41.90

Installing Machinery

Began Nov. 5; completed Nov. 27

480 man-hours @ 20 ct.	$ 96.00
170 man-hours @ 12½ ct.	21.25
603 man-hours @ 17½ ct.	105.52
Total installing machinery	$222.77
Total cost of erecting dredge	$464.17

Dredging with Steam-Shovel Mounted on a Hull. *Engineering News*, Jan. 18, 1917, gives the following:

On canal clean-up work at Trenton, N. J., the Pennsylvania R. R. is using the machinery of a small revolving steam shovel mounted on a wooden hull. The boom and dipper handle are

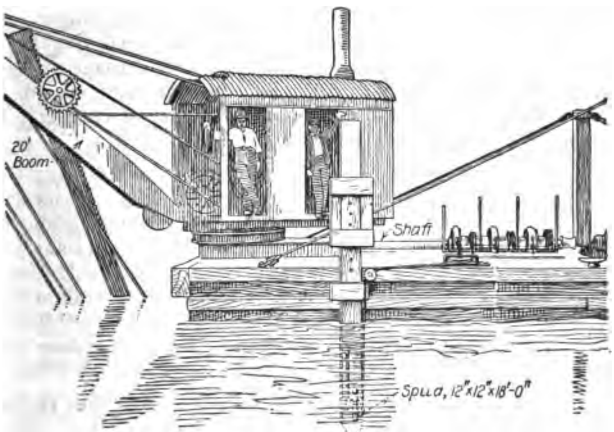


Fig. 7. How the Spuds on a Floating Shovel are Operated.

especially long, making it possible to dig to a depth of 9 ft. below water and dump material 28 ft. from the centerline of the boat and 6 ft. above water. The hull is 40 x 18½ ft. in plan by 4½ ft. deep. The outfit is efficient for digging small ditches or for dredging shallow streams. It is cheaper to build than a regular dredge for the same service and is cheaper to operate. The shovel used is of the Osgood 18 type.

The truck frame of the shovel — axle and axle bearings removed — is bolted to the hull. The heavy end-plate is bolted both to the shovel frame and (by means of an extension plate) to the hull.

The special parts required to build this outfit are the spuds, spud machinery, backing drum at the foot of the boom, and the hull upon which the machinery is mounted. The general arrangement is shown in Fig. 7.

To move the dredge forward: First, the dipper is placed far ahead; next, the hull is floated by raising the spuds; then, by starting the boom engines, the hull is caused to move toward the dipper. The spuds are then dropped, thus anchoring the hull, when the dredge is again ready to excavate.

Costs of Dredgework on the Los Angeles Aqueduct. *Engineering and Contracting*, May 31, 1911, gives the following:

The costs of dredging are taken from the monthly report for February on a section of the Los Angeles aqueduct through the Owens Valley. The dredge consists of a scow on which is mounted a No. 60 Marion electric shovel with a 1½ cu. yd. dipper. The cost of the dredge was $19,897 and was built according to the specifications of the aqueduct engineers. The yardage is based upon the theoretical section of the aqueduct or 14.81 cu. yd. per lin. ft. This is exceeded a small amount by excess cutting. The following are the data for February:

Men — number days	459
Live stock — number days	68
Lineal feet	2,625
Cubic yards	38,876
Labor costs	$1,618.34
Live stock costs	61.20
Cost materials and supplies	122.07
Power cost	418.30
Freight cost	24.41
Total costs	$2,244.32
Cost per cu. yd.	$0.0565

The cost per cu. yd. for the month figures 5.65 ct., but the unit cost given for the work of the dredge to date is 6.7 ct.

A Steam Shovel Dredge. *Engineering and Contracting*, Dec. 25, 1907, gives the following: A steam shovel mounted upon a barge was used in securing gravel from the beds of streams for ballasting purposes. The gravel was obtained from streams which contained very little water during nine months of the year. The barge used cost about $1,000 and had a deck 20 x 50 ft. Upon this was securely mounted on a track a steam shovel weighing 78,000 lb. and having a dipper capacity of 1½ cu. yd. The barge drew 2⅛ ft. of water. In excavating the gravel, the

steam shovel was run forward on its track, the bow of the barge sinking and practically resting on the bottom, although for safety four 10 x 10-in. spuds at the corners of the barge were used to hold the barge stationary. The gravel was loaded into cars on a temporary track alongside the bank. When the gravel within reach of the dipper had been exhausted, the shovel was moved back on the track, the bow of the barge rising. The barge was then advanced and again secured by spuds. The cost of securing the gravel was about 4 ct. per cu. yd.

Hydraulic Jet Equipment for Leveling Spoil Banks. Chester B. Loomis, in *Engineering News*, July 31, 1913, gives a description of a dipper dredge built especially for cleaning a part of the channel for the Los Angeles River and for building levees. The special feature of the equipment was the hydraulic giant for leveling the spoil banks.

This dredge was equipped with a 1½-yd. bucket, 55-ft. boom, and a dipper handle of such length as to enable it to dredge 10 ft. below the water surface. The hull was of steel 75 x 32 x 6 ft. in size, strongly braced longitudinally and transversely with bulkheads and braces. The hull proved very satisfactory and was lower in cost than a wooden hull. It was erected and bolted together in the shop, the parts were then marked, dismantled and shipped knocked down by wagons. The entire hull was riveted together in 10 days by 8 men and 1 foreman.

The standard equipment of this dredge comprised an 8 x 10-in. hoisting engine, a 6 x 7-in. swining engine, three 12-in. drums and spud hoists, and a boiler working at 125 lb. pressure. In addition to the regular machinery a second locomotive boiler and a compound duplex steam pump, 9¼ x 10 x 12 in. in size, were installed. This pump supplied water to 2 hydraulic giants each mounted near the bow.

The method of carrying out the work was as follows: Brush was cut in advance of the dredge and piled on each side of the line of the cut and about 10 ft. back from it. The channel being 80 ft. wide it was found more economical to have the day shift make a cut half the width of the channel, piling the material on one side of the brush. After making a cut and when the dredge was moved ahead for the next cut, the sluicing pump was started and a jet was played on the spoil bank. As the bank was directly opposite the giant, the water jet was very effective and it was found that the bank could be cut down into a levee about 7 ft. high, with a top about 10 ft. wide, in about one-half the time it took to excavate it with the dipper. At the end of the day the dredge was moved back so that the night shift could start the dredge on the part yet unexcavated, the same method of sluicing

being employed. The spoil was largely sandy loam and silt with occasional clay and washed very easily. Stumps were washed back or buried by undermining. Water pressure at 30 to 35 lb. per sq. in. was most effective.

The Cost of Dipper Dredge. *Engineering and Contracting*, May 29, 1912, gives the following notes on the cost of dredging, abstracted from a report by B. F. Powell, Engineer for the Fort Lyon Canal Co., at Las Animas, Colo.

The dredge was built under the supervision of the Marion Steam Shovel Co. Work on it was commenced April 3 and the hull was completed and launched on May 26, 1911. The boilers were steamed up on June 5 and used from that time on to furnish power for erecting the balance of the machinery. The fifteen-day test was begun on July 1, when it was demonstrated that the dredge would excavate its estimated yardage.

The hull of the dredge is 100 x 41 x 8 ft. and required 135,000 ft. B. M. of lumber. It has two 120-hp. boilers, one double 10 x 12-in. hoisting engine, a double 8 x 10-in. swinging engine, an 80-ft. boom and a 2½-yd. bucket. The amount of work accomplished by the dredge in the soft material in which it worked, was:

	Cu. yd.
July	74,000
August and September	130,000
October	71,750
Total	275,750

The cost of operation as given for the month of October was 3.15 ct. per cu. yd.

The dimensions of the irrigating and storage canal now being completed, are 120 ft. on top and 100 ft. on the bottom for the first two miles from the head gate; for the next mile the width is 20 ft. less and after the third mile the width is again reduced 20 ft., making the bottom width 60 ft., with 1:1 slopes. The depth is 10 ft.

The cost of the dredge and operating expense for one season were:

Materials:	
Dredge equipment	$14,932.00
Extra boiler	1,600.00
Electric light plant	500.00
Freight	413.96
Tools	250.00
Extra machinery	571.17
Boiler flues	236.80
Oakum	4.50
Steel and castings	427.70
Wire rope	510.75
Oil	317.27
Coal and hauling	2,896.68

Hardware	1,880.22
Groceries and camp supplies	1,611.45
Lumber	5,033.27
Total materials	$31,185.77
Labor:	
Constructor	$ 584.70
Foreman	984.92
Cook	155.00
Dredge runner	722.83
Labor	1,717.03
Carpenters	1,232.05
Hauling	404.45
Sundry expenses, materials, teams, labor	2,818.33
Total labor	$ 8,619.31
Total, labor and material	$39,804.08

The above table shows the cost of the dredge, its construction and its operation until the end of the season, Nov. 1, 1911, as shown by the company's books. If we multiply the yardage excavated by about 4 ct. (the cost of operation) and deduct this amount, $11,030, from the total shown in the table the result should give the cost of the dredge ready for operation. This is $28,774.

Cost with Dipper Dredge on the Massena Canal. The cost of dredging on the Massena Canal is given by John Bogart in a paper read before the International Navigation Congress (see *Eng. News*,, Oct. 30, 1902).

For excavating indurated clay and boulders that could not be handled by a centrifugal dredge nor an orange-peel dredge, a dipper dredge with a 2½-yd. dipper was used. This machine excavated from depths as great as 20 ft., loading into scows. Two scows were employed, each having a capacity of 140 cu. yd. The dredge excavated an average of 754 cu. yd. per 10-hr. day for 183 days. The loaded scows were towed during the day 5,500 ft. to the dumping grounds.

The cost of the dredge, scows and tug was $43,000. In the tabulation following repairs and renewals are estimated at 10% per annum and interest at 4% per annum, the daily cost being figured on the basis of the actual number of days, 212, worked per year.

The cost was as follows:

	Per day
Labor, supervision, coal, supplies	$30.56
Interest, repairs, renewals	28.80
Care during winter	1.00
Total daily	$60.36

This is equal to a cost of 8 ct. per cu. yd.

A $1\frac{1}{2}$-yd. dipper dredge worked one season, the unit cost of dredging being 8 ct. Dredging with a 6-cu. yd. dipper dredge also cost practically the same.

It should be noted that dredges can not ordinarily be expected to average 212 days worked each year.

Cost with a Small Dipper Dredge, Florida. The cost of dredging mud and sand at Manatee River, Florida, during August and September, 1887, is given by W. M. Black on p. 38 of "The United States Public Works." The depth dredged was 8 ft.; the depth of cut was 2 to 4 ft. The average distance to the dumping grounds was 3.5 mi. The plant employed consisted of 1 dipper dredge, 2 tugs, and dump-scows. The time occupied was 48 days, of which 25 days were worked.

The working time was consumed as follows:

Dredge working	100.1 hr.
Dredge idle, waiting for tug	89.5 "
Dredge idle, repairing machinery	3.2 "
Dredge idle, shifting and moving	57.5 "
Dredge idle, pumping scows	17.2 "
25 days at 10.7 hr. each	267.5 hr.

The total amount dredged was 15,302 cu. yd., the amount dredged per working day being 612 cu. yd.

Dredge: 48 working days	Per cu. yd.
Captain at $125 per month, plus $15 board	$0.015
Engineman at $60 per month	0.008
Crew of 7 men at $30 per month	0.033
Tug: 48 working days	
Captain at $90 per month, plus $15 board	0.011
Engineman at $60 per month	0.008
2 firemen at $30 per month	0.010
2 deck hands at $30 per month	0.010
Tug: 28 working days	
Captain at $90 per month	0.006
2 enginemen at $60 per month	0.009
2 firemen at $30 per month	0.005
2 deck hands at $30 per month	0.005
Materials:	
Wood for dredge, 7 cords daily at $3 for 31 days	0.043
Wood for tug, 4 cords daily at $3 for 37 days	0.029
Wood for tug, 5 cords daily at $3 for 24 days	0.024
5 guide piles at $5.	
Dredge, interest, depreciation and repairs	0.106
Tug, interest, depreciation and repairs	0.011
Tug, interest, depreciation and repairs	0.008
Total per cu. yd.	$0.341

Dredging a Canal on the Florida Coast. George P. Miles gives a description in *Engineering News*, Apr. 25, 1904, of the methods

used in excavating canals that connected lagoons along the Florida coast. At first elevator bucket dredges were used, but these were soon abandoned, owing to the constant wear on the links connecting the buckets. In a personal letter to the author, Mr. Miles states that the Florida sand cut the links of the bucket-ladder so rapidly as to cause numerous delays. Furthermore, the cost of repairing dredges in Florida is larger than in a country where machine shops and manufacturing facilities are at hand. Although duplicate parts were kept in stock, the repair costs were very high, as will be seen in the statement of operation expenses given later. Clamshell, suction and dipper dredges were also tried, the last two being most effective. Osgood dipper dredges for hard ground and suction dredges for shoals of recent formation were found most efficient.

In dredging soft mud with dippers the mud would slide so badly that it was found necessary to attach a long chute to the A-frame of the dredger, and to dump into the chute. The material would spread over the adjacent marshes in a thin layer.

Dredges on the Chicago Canal. The material on Sections O of the Chicago canal was excavated mainly by steam dipper dredges, loading into scows that were towed out to Lake Michigan and there dumped. A description of the work is given by Mr. Alex. E. Kastl in *Journal, Association of Engineering Societies*, vol. 14, April, 1895, from which the following data have been abstracted:

The largest number of dredges employed at any one time was five, of which four worked steadily from May 15 to December 27, 1894. During this period 400,262 cu. yd. were dredged; the average output per 10-hr. shift per dredge was 606 cu. yd., and the average scow load was 184 cu. yd. The largest average output per 10-hr. shift per dredge in any month was 870 cu. yd., and the least was 330 cu. yd.; the latter low output being due to the fact that the dredges were mainly engaged in finishing the bottom and the side slopes. The largest average scow load was 230 cu. yd., and the least was 140. The largest amount excavated by any one dredge in 10 hr. was 1,800 cu. yd. The dredges varied in size, but all had hulls about 90 x 32 x 9 ft., 2½ to 3⅛-cu. yd. dippers, and burned 2½ to 3½ tons of coal per 10 hr.

10-yd. Dredges on the Cape Cod Canal, Mass. Two very powerful dredges constructed for excavating the Cape Cod Canal during 1912 are described in *Engineering News*, Feb. 19, 1914 These machines were 10-cu. yd. dipper dredges. The hulls were of steel, 135 ft. long, 42 ft. beam, and 10 to 12 ft. deep. The crowding engine was a 12 x 15-in double cylinder, and the main engine an 18-x 24-in. double cylinder engine. The dipper handles were 70 ft. long, enabling the dredge to dig in 40 ft. of water.

The dredges began excavation Sept. 1, 1912. Slight progress was made during the fall, the working out of defective parts causing frequent stoppage. In January, 1913, the excavation of the two dredges amounted to about 32,000 cu. yd. per dredge per month. The dredges were subjected to two months of repairs and changes, were returned to the Canal in March, 1913, and began working continuously three 8-hr. shifts per day. Each then averaged very nearly 100,000 cu. yd. place measure per month. In June and July, 1913, the "Governor Herrick" excavated 120,000 and 131,000 cu. yd. place measure.

The season's performance by the "Governor Warfield" was more uniform. The output increased from 50,000 cu. yd. per month to 110,000 cu. yd. in July, and was maintained at a rate of 120,000 cu. yd. per month throughout August and September, 1913. The material was sand.

Cost of Dredging on the N. Y. Barge Canal. A description of some performances of dipper dredges on the New York State Barge Canal is given by Emile Low in *Engineering and Contracting*, Apr. 29, 1914.

The contract in general provided but one price for all excavation, a lump sum for each cubic yard of material excavated of every name and nature; and no attempt was made to classify the materials excavated.

Contract No. 19 is prism excavation in Tonawanda Creek. This included about 2,842,000 cu. yd. of sand, gravel, clay, etc., which was let at the contract price of 17.5 ct. Among the various machines working on this contract was a dipper dredge, the "Buffalo," with a hull 86 ft. long, 29.5 ft. wide, and 8 ft. high. This hull was constructed of the best grade of long-leaf, yellow pine. The main engine was a 12.5 by 15-in., double cylinder. The swinging engine was a 10 by 10-in., double cylinder. The boiler was of the Scotch marine type, 8.3 ft. in diameter and 10 ft. long. The pinning up engine was 7½ by 7-in., double cylinder. The dredge was equipped with a 2.5-cu. yd. hard-digging dipper, and a 3.25-cu. yd. soft-digging dipper. It could excavate to a depth of 23 ft. below water. The cost of the machine was about $35,000.

The work of the dipper dredge at the start was mainly excavation of the prism, the material being deposited in dump scows, towed to points near the shore, dumped and redredged by two clam-shell dredges, with booms of 80 and 100 ft. respectively, the dumped material being then rehandled into spoil banks. Later on the dipper dredge was rebuilt and was used to dredge the hard material, encountered on the bottom of the prism, which in time verged close to hard sand. This hard material was

dumped in various places along the creek, and was later handled by the hydraulic dredge "Niagara." The following tabulations show the output of the dipper dredge for a number of years:

Year	Cu. yd.
1908	132,687
1909	28,100
1910	81,873
1911	30,500
1912	168,192
Total	441,352

The following gives the month cost of labor for running the dredge for a double shift of 16 hours:

1 captain	$ 157.50
1 runner	137.50
2 cranemen at $106.50	213.00
2 oilers at $77.50	155.00
2 firemen at $77.50	155.00
4 deckhands at $67.50	270.00
4 scowmen at $67.50	270.00
1 watchman	60.00
1 blacksmith	75.00
Total monthly cost	$1,493.00

As the average monthly output of the dredge was only about 10,000 cu. yd., and as the contract price was 17.5 ct., amounting to about $1,750 per month, it is apparent that this price barely covered the expense of wages and coal.

Blasting a Pit for a Dipper Dredge. F. W. Wilson, in *Engineering News*, gives the following: Two large ditches were to be dug in New Madrid County, Missouri. The contractor owned two dipper dredges, but there was no basin in which to float a dredge in order to start the ditching. A pit was required 136 x 50 x 6 ft. deep. It was decided that this could be formed quickest by blasting. The hole was shot by a professional dynamiter.

Bore holes were put down, running the length of the proposed pit, in eleven parallel rows 3 ft. apart. The holes in the middle row were each loaded with 2½ lb. of dynamite. The holes in the two rows on either side of the middle line were spaced 15 in. apart in the row and each loaded with 2 lb. of dynamite; the holes in the next two rows were loaded and spaced the same way. The spacing between holes in the next two rows was 2½ ft. and the loading 1½ lb. per hole; in the next two rows the holes were 2 ft. apart, and each was loaded with 1 lb. The holes in the two outside rows were spaced 18 in. apart and loaded with ½ lb. each. In all, 950 lb. of dynamite was used.

The result of the shot was a pit 43 ft. wide, 136 ft. long and 7 ft. deep in the center, with an average depth of 3½ ft., with

the exception of one spot where a large cypress stump had stood and which caused the dirt to pile up. The blaster claims that he did not want to blast the pit in one shot, but the contractor wanted it done that way and so he acquiesced. The blaster's idea was to blast out two pits and then shoot out the division. By this method much less earth would have fallen back into the excavation.

Operation of 15-yd. Dredges on the Isthmian Canal. *Engineering and Contracting*, Oct. 17, 1917, gives the following: In the early part of 1914 the Isthmian Canal Commission began operating two 15-cu. yd. dipper dredges on the completion of the channel through the Gaillard Cut of the Panama Canal. These dredges — the Gamboa and Paraiso — were built by the Bucyrus Co., the total cost including the towing to the Isthmus, being $573,287. The dredges operated so efficiently that the Commission placed another contract with the Bucyrus Co. for a third dredge, of improved design, the Cascadas. The dredge was placed at work in Gaillard Cut on Oct. 31, 1915, at a total cost of $376,180. An interesting study of the design, operation and efficiency of these dredges was given by Mr. Ray W. Berdeau in a paper presented Sept. 19, before the American Society of Civil Engineers, from which the matter in this article is abstracted.

The following are the principal dimensions, etc., of the Gamboa and Paraiso:

Length of hull	144 ft. 0 in.
Beam, moulded	44 ft. 0 in.
Depth, moulded	13 ft. 6 in.
Draft	8 ft. 0 in.
Digging depth, below water line	50 ft. 0 in.
Displacement	1,730 tons

One main engine, two cylinders, compound, 16 by 28 by 24 in.
One swinging engine, two cylinders, compound, 12 by 16 in.
One backing engine, two cylinders, compound, 12 by 16 in.
Two forward spud engines, two cylinders, compound, 12 by 16 in.
One stern spud engine, two cylinders, 9 by 9 in.
Two deck winches, two cylinders, 6 by 6 in.
Two boilers, Scotch marine type, 126 in. diameter, 138 in. long, water pressure, 150 lb.
Two forward spuds, 48 by 48 in., and 82 ft. long.
One stern spud, 30 by 30 in., and 83 ft. 6 in. long.
Swing circle, 24 ft. in diameter.
Bail pull, 235,000 lb.
Hoisting pull on spud rope due to engine, 88,000 lb.
"Pin up" pull on single cable, with brake on engine, 160,000 lb.
Capacity of rock dipper, 10 cu. yd.
Capacity of mud dipper, 15 cu. yd.
Capacity of fuel oil tanks, 14,200 gal.

The displacement of the Cascadas is 2,095 tons, and the hull is 144 ft. long, 55 ft. beam, and 15½ ft. deep. Thus, it is 11 ft. wider than the others, making less reactions on the spuds, less

metacentric variation when digging over the sides, and it allows the spuds to be inset. The spud-well construction differs from that of the Gamboa and Paraiso, as their forward spuds are placed outside the hull, with tapering sponsons fore and aft to transmit the reactions to the sides of the hull.

The dredges were supplied with interchangeable buckets of two sizes, one with a capacity of 15 cu. yd. and another of 10 cu. yd., for use in rock excavation. Having been placed in Gaillard Cut in rock digging exclusively, the larger dippers have been seldom used; the smaller ones, as supplied by the contractors, were of extra massive construction, but were of insufficient strength to withstand the severe use and the impact from a dipper stick load of 131,000 lb., and were replaced later by the Missabe type of cast manganese-steel dippers. The over-all dimensions of the new dipper are 10½ by 9 by 9 ft.; the lips are 3¼ in. thick at the bottom bands, and the body consists of a front and back casting with lap-riveted joints at the sides; and, in addition, the lip is a separate casting riveted to the front piece and joined thereto by the rivets of the tooth ribs.

All three dredges have been working until recently in Gaillard Cut of the Panama Canal. The material excavated consisted of hard and soft rock, to depth of from 35 to 47 ft. The accompanying costs include operation, that is, wages of crew, subsistence of crew, fuel and lubricants, maintenance, that is, the cost of keeping the equipment in first-class physical condition, and maintenance only. Extra heavy 10-yd. manganese-steel dippers were used on this work, the dredges working continuously in three 8-hr. shifts.

YARDAGE EXCAVATED BY FISCAL YEARS

July 1, 1913, to July 1, 1914

	Cu. yd.	Per cu. yd.
Gamboa	1,825,122	$0.1278
Paraiso	69,812	0.2931
Cascadas	......	......

July 1, 1914, to July 1, 1915

	Cu. yd.	Per cu. yd.
Gamboa	1,825,122	$0.1278
Paraiso	1,739,228	0.1313
Cascadas	......	......

July 1, 1915, to July 1, 1916

	Cu. yd.	Per cu. yd.
Gamboa	3,097,226	$0.0731
Paraiso	3,004,104	0.0769
Cascadas	2,400,492	0.0651

July 1, 1916, to Oct. 1, 1916

	Cu. yd.	Per cu. yd.
Gamboa	599,575	$0.0713
Paraiso	818,095	0.0658
Cascadas	666,656	0.0742

World's Dredging Record at Culebra. According to *Engineering and Contracting*, May 3, 1916, from midnight to midnight on Feb. 18, 1916, the 15-cu. yd. dipper dredge "Cascadas," working in Gaillard (Culebra) Cut, Panama Canal, excavated 23,305 cu. yd. of rock and earth. This is believed to be the world's record.

The actual working time of the "Cascadas" having been 23 hr. and 15 min. during the record day, the rate of output was slightly over 1,002 cu. yd. an hr. This is about 1,500 tons an hr. or 25 tons a min. The "Cascadas" was built by the Bucyrus Co., South Milwaukee, Wis., and of her record the *Canal Record* says: The 15-yd. dipper dredge, "Cascadas," was placed in commission on Oct. 31, 1915, and was in the cut continuously until March 20, when she was brought to the repair dock at Paraiso for renewing the starboard spud. During that time, slightly over 4½ months, the "Cascadas" excavated 1,447,946 cu. yd. and was delayed by breakdowns 77 hr. and 35 min. Her average excavation was 466 cu. yd. per hr., over a working period of 3,104 hr. The dredge was engaged throughout in excavating rock. The loss of time from breakdowns was only 2.44% of the total working time.

Ladder Dredges. Ladder Dredges are known as bucket-elevator dredges, chain-bucket dredges, endless-bucket dredges, conveyor-bucket dredges, etc. This type of dredge is a favorite abroad, but in America it is confined mainly to canal work and to gold dredging. The comparatively rare use of this type of machine is due to the relatively high first-cost and the larger crew required, as well as the fact that other types of dredges are suited to work of more widely varying nature. The introduction of special steels has reduced the wear on such working parts as chains and buckets, to a large extent, making this type of dredge one of the most efficient for work of large extent, except where the material is of an extremely abrasive nature. (See the fore part of this chapter for a description of the difficulties encountered when using elevator dredges in Florida.)

As the name of this dredge implies, it has an endless chain of buckets which cut into and scoop up the material, and elevate it to the top of the ladder on which the line of buckets travels. There the material is delivered to an inclined chute or a travelling belt conveyor. The earliest forms of these dredges had chutes inclined 1 in 10 for clay and 1 in 20 for fine sand, but long chutes became clogged. On the earlier work on the Panama Canal auxiliary jets of water had to be provided to keep the chutes clean. Wet clay will slide down chute inclined 1 in 5 to 1 in 3, if the material is comparatively free from sand. Wet

sand will not slide down an incline of even 1 in 2 without a free flow of water. According to J. J. Webster, when the volume of solid is diluted with 2 or 3 times its volume of water, the best angles for chutes are as follows: for soft mud 1 in 10; for soft clay 1 in 12 to 16; for fine sand and water 1 in 25. On the Suez Canal work it was found that when fine sand was mixed with equal quantities of water it would flow down a slope in 1 in 25.

The modern bucket-elevator dredge has an endless belt conveyor instead of an inclined chute, which reduces the height to which the material must be raised and delivers it with the certainty of not becoming clogged.

The output of a bucket-elevator dredge depends on the capacity, and quantity of the buckets, the mode of power transmission from the engine to the dredging apparatus, the size of dredge, as well as the methods of operating and the local conditions such as the character of the soil.

Mr. J. J. Webster in 1887 read a paper before the Institute of Civil Engineers (England) in which the gave the following formula, based upon actual tests.

Hp. $= 0.04\,T \sqrt{H}$ for stiff clay; hp. $= 0.026\,T \sqrt{H}$ for soft mud; hp. being the indicated horsepower required to excavate and raise T tons per hr. to a height of H ft. Where $T = 450$ and $H = 40$, he found hp. $= 98$ in one case, or 1 hp. excavated nearly 4.5 tons per hr. In the *Transactions of the American Society of Mechanical Engineers*, 1886–7, A. W. Robinson, the well-known designer of dredges, gives a paper on bucket elevator dredges in which he says that certain indicator cards showed that 1 hp. would excavate 5 to 9 cu. yd. per hr. on a bucket elevator dredge, both working in the same kind of tolerably yielding material in water 32 ft. deep. If we assume a total lift of 40 ft. 1 hp. should raise 16½ cu. yd. (3,000 lb. per cu. yd.) of earth per hr., if there were no loss in friction of machinery, no dead weight of buckets and water to lift and no force consumed in loosening the material.

The bucket elevator dredge is used almost exclusively where gold bearing gravel is excavated. It is claimed that the dipper dredge stirs up the gravel to such an extent that the gold settles and escapes; and further losses of gold occur through the cracks between the door of the dipper and the sides of the dipper. The writer is not inclined to accept this theory of gold loss, but it is desirable to have a dredge like the bucket elevator that delivers a steady stream of gravel instead of an intermittent stream.

Dredging Silt Bars, Muscle Shoals Canal. A paper by A. D.

Edwards appearing in *Professional Memoirs* for January–February, 1912, is quoted by *Engineering and Contracting*, Jan. 17, 1912. The Muscle Shoals Canal is divided into two parts, locally designated as the upper and lower divisions, which are separated by 8 miles of open river. The upper division consists of two locks connected by a mile of canal, an upper pool 2½ miles long, and a dredged channel below the lower lock. The lower division is composed of 14½ miles of canal and nine locks. Fifteen streams varying in size, empty directly into the canal. Though none of them is very large, yet at every freshet they bring down sediment, and bars are constantly forming in the channel opposite their mouths. At the entrance to both divisions of the canal a large amount of silt also accumulates at every high water, and constant dredging is therefore required to keep it cleaned.

A Bucyrus dredge of the elevator type is employed on the canal for this purpose, having the following general dimensions: Length, 80 ft., width in center, 38 ft.; width at each end, 13 ft.; depth of hull, 6 ft. The sides are circular, being struck with a 68-ft. radius so as to give the above dimensions. Draft when working, 42 in.

A chain of 24 buckets and 24 links is mounted on a ladder frame 48 ft. long, equipped with truss rods and fittings, rollers with shafts and bearings, top and bottom tumblers, device for holding bucket chain, and hoisting tackle for regulating the depth of cut. This chain of buckets works over the forward end of the boat, and slops back at an angle of 45° until it reaches an elevation of about 22 ft. above the deck, where the material is discharged into a hopper. This chain of 24 buckets, each having a capacity of 5 cu. ft., makes one complete revolution in 1¼ min., discharging 4.44 cu. yd. per revolution, which gives the dredge a capacity of 213 cu. yd. per hr., or 2,130 cu. yd. per day of 10 hr.

From the hopper, which is located 15 ft. above the center of the boat, a discharge pipe 26 in. in diameter and 80 ft. long, suspended by a set of tackle attached to an A-frame, conducts the material that is dumped into the hopper to the place of deposit, which is usually beyond the tow-path. When the material is thick and heavy, a stream from a 6-in. pump is turned into the pipe to keep it flushed out.

The dredge is equipped with a 10 x 14-in. double cylinder engine making 140 revolutions per min., developing 40 hp. The swinging engines are double cylinder, 8-in. diameter and 8-in. stroke. The boiler is of marine type, 40 hp., 60 in. in diameter, 17 ft. long, and carries a pressure of 90 lb. For flushing the discharge pipe a Gordon Duplex steam pump is used, having 12-in.

steam cylinders, 10-in. plungers, and 16-in. stroke; capacity, 326 gal. per min.

This dredge, when in operation, revolves about a center spud, which is 40 ft. from the point of the buckets, thus enabling a cut 80 ft. wide to be made. The depth of the cut varies from 3½ to 10 ft. below the surface of the water.

This dredge has an advantage over other types, as it cleans the entire width of the canal as it moves forward, and deposits the material outside of the canal bank, where it does not have to be handled again. The canal is cleaned with a single cut, with the exception of a few places where two cuts, and sometimes three, have to be made before the material is finally deposed outside the canal bank. This method is a little slow, but it is the best way to handle the work, as it would not be practicable to load the material in scows and tow them outside of the canal. Above Lock A (upper division) three cuts have to be made, and between Locks 1 and 2 (lower division) three cuts are necessary. Another point where some difficulty is experienced in operating the dredge is above Lock 1, where the banks are too high for the discharge pipe to reach over them. To dredge this part of the canal the river has to be caught at a stage that will allow the discharge pipe to clear the bank.

The crew necessary to operate the dredge consists of one dredge runner, one engineman, one fireman, one spudman, and two linemen.

The hull of this dredge was built at Chattanooga, Tenn., by contract, in 1891. The machinery was placed on the hull and floated to the canal, where the cabin was built and machinery installed. The total cost of the dredge was approximately $20,000. The hull was rebuilt at the canal by hired labor in 1902 and 1903, at a cost of $10,000, being put back in commission in October, 1903. The dredge has been operated almost continuously since it was rebuilt. A new hull will have to be built within the next year or two, also a complete set of new buckets and links will be required. The machinery is in good condition and will outlast another hull.

The following statement gives the number of cu. yd. dredged with cost of labor, material, and field repairs since the dredge was put in commission.

Year	Cu.yd.	Per cu.yd.
1892	27,210	
1893	38,964	
1894	42,800	
1895	13,235	
1896	5,513	
	127,722	$0.036

Year	Cu. yd.	Per cu. yd.
1897	61,550	.039
1898	62,097	.041
1899	39,375	.036
1900	59,200	.038
1901	18,093	.144
1902	55,764	.031
1903	38,123	.028
1904	100,012	.030
1905	105,490	.031
1906	146,968	.030
1907	111,337	.023
1908	59,372	.056
1909	117,777	.046
1910	195,982	.036
*1911	87,731	.036
	1,386,593	$0.036

Total cost of labor, material and field repairs	$51,302
Cost of rebuilding hull in 1902 and 1903	10,000
Deterioration of plant	10,000
Total cost of dredging since 1892	$71,302

*To Jan. 1, 1911, of fiscal year ending June 30, 1911.

This gives for the unit cost of dredging 1,386,593 cu. yd. of material, 5.11 ct. per cu. yd.

Trestle Filling with a Ladder Dredge. *Engineering News*, Aug. 4, 1892, gives the following: Near New Orleans, La., a railway trestle 18 miles long and 7 to 10 ft. above the ground and water level, was filled with material obtained by excavating a canal alongside and 50 ft. away. A bucket elevator dredge with a hull 40 ft. wide, 40 ft. long, and 6 ft. deep, equipped with a 90-ft. belt conveyor, was employed. This machine excavated 472,934 cu. yd., or 34,170 lin. ft. of cut 6 ft. deep by 60 ft. wide, from Jan. 1, 1891 to April 30, 1892, an average of 2,135 lin. ft. or 29,558 cu. yd. per month, or 1,180 cu. yd. per day, measured in cut. A 10-hr. day was worked, but passing trains reduced the actual working time to 7 hr. per day. Many sunken logs and cypress roots were encountered and material retarded the work. The dredge required a crew of 6 men. Excavation cost about 3 ct. per cu. yd.

It is interesting to note that in this material the original rubber conveyor belt was still in service after having conveyed 473,000 cu. yd.

High Cost of Dredging at Havana, Cuba. A. H. Weber, in *Engineering Record*, Nov. 23, 1901, gives some cost data of dredging at Havana. A bucket-ladder dredge with a "capacity" of 1,000 cu. yd. in ordinary harbor mud, but only 200 to 600 cu. yd. in hard clay, was used. In addition to small clamshell dredges, of the Prestmann type, with ¾-cu. yd. bucket, and "ca-

pacity" each of 200 to 400 cu. yd. in mud, were worked. These machines were not at all effective in hard clay.

Rock and very hard clay were encountered, and had to be blasted. An Ingersoll auto-feed 4½-in. cylinder drill was hung in the leads of a floating pile driver. This machine drilled through a telescopic tube from 4 to 12 in. in diameter. The charges were loaded in the holes by a diver. At first 10 holes spaced 5 ft. apart in a row were blasted to the requisite depths of 12 to 16 ft., but it was claimed that the charges injured adjacent buildings. The holes therefore, were drilled only 6 to 8 ft. deep and charged with 6 lb. of 60% dynamite each. The whole area, therefore, was removed in two or three lifts. The number of holes drilled was 1,682, and 5,600 lb. of dynamite were used. If the clay was allowed to remain undredged after being blasted, it would become hard and require reblasting.

The total amount of material dredged measured 47,970 cu. yd. scow measure, of which about 10,500 cu. yd. were stone. The unit cost of stone excavation exceeded that of the clay by about 75%. The total cost of the work was $35,734.

	Per cu. yd. ct.
Dredging, wages, supplies and repairs	49.2
Dredging, wages, supplies and repairs	12.3
Explosives	2.8
Moving scows to sea 3 miles	7.6
Office operation and superintendent	2.6
Total per cu. yd.	74.5

The work was done by day labor for the government.

A Ladder Dredge with a Belt Conveyor System. In *Engineering News*, Oct. 25, 1906, I. M. Mann gives the following: On the Fox River, Wisconsin, dredging over a period of 50 years by dipper and clam-shell dredges had formed high spoil banks on each side of the channel. These were unsightly, objectionable to property owners, and were subject to erosion by the current, necessitating a second and third dredging of about 25% of the material. To overcome this objectionable practice, a dredge was designed to fulfill the following conditions:

(1) Ability to dig all materials except solid rock or equally hard material;

(2) Ability to cut full width of channel without moving the dredge sideways;

(3) Ability to convey the spoil a considerable distance without rehandling;

(4) Ability to obtain the greatest possible area of distribution of spoil and to deposit either side of the channel and in low places or scows;

(5) Ability to carry the spoil in places over old dredge banks not less than 20 ft. in height and to distribute it without forming new banks.

These conditions were fulfilled by the "conveyor dredge." This plant consists of a dredge with two intermediate conveyor scows and one delivery scow. The delivery scow can be attached directly to the dredge if desired. The dredge is of the regular bucket-elevator type, having 30 buckets of 5 cu. ft. capacity each, equipped with steel cutting teeth. It is able to dig to a depth of 10 ft. The dredge hull is of fir, 75 x 31 x 6 ft. in size. It is equipped with a 9 x 12-in. and a 6 x 6-in. engine, a 35-kw. electric generator, and electric motors. Steam is supplied by a marine boiler 10 ft. long.

The intermediate scows are 40 x 15 x 3 ft. in size, and each carries a belt conveyor 32 in. wide and 65 ft. long, driven by electric motors. The delivery scow is nearly triangular in shape, being 31 ft. long and 16 ft. wide at the delivery end. It is furnished with a delivery belt conveyor supported by a derrick, and overhanging the stern by about 40 ft. The delivery end of this conveyor can be raised to 20 ft. above water to suit the height of the spoil bank. The total length of the outfit is 300 ft.

The dredge is furnished with a turning spud at the stern amidships, and a walking spud slightly forward and to starboard. It is moored to shore anchors by bow lines, and digs in a circle of about 80 ft. radius, covering a width of channel of 145 ft. In operation the material leaving the elevator buckets at the top of the ladder passes into a hopper, thence to a belt conveyor that carries it to the stern of the dredge, thence to another hopper, and finally, by the various conveyors on the scows, to the shore.

The crew consisted in 1906 of 9 men. The cost of operation, including fuel, was $30 per day. In ordinary digging the dredge excavated 400 cu. yd. per hr. in a trial test, and in very tough clay and hard pan 200 cu. yd. per hr.

Bucket-Ladder Dredge with Long Chutes. In a paper in the *Proceedings of the Institute of Civil Engineers* (Great Britain), John B. Body gives a description of the drainage of the Valley of Mexico. His paper is quoted in *Engineering Record,* Aug. 10, 1901.

Part of the work was excavated by Indians, who carried baskets on their heads, and part by a grab-bucket on a cableway. The main part of the canal, however, was dredged with 5 "couloir" or long-chute dredge of the bucket-ladder type. These machines had main engines of 150 hp. One of these dredges was of large size with the top tumbler of the bucket-ladder at a

height of 74.5 ft., while the other four had top tumblers at a height of 56 ft. The material was discharged from the bucket-ladder on to the chutes. These extended 165 ft. from the center of the dredge over the bank of the canal. Pumps, discharging as much as 600 cu. ft. of water per min., facilitated the passage of the dredged material through these chutes. At times the material was discharged as far as 185 ft. from the center of the dredge.

The ladders were 78 ft. long, and the buckets had capacities of 11 cu. ft. each. In very sticky soil, hinged bottoms were used on the buckets with exceptional success.

The maximum depth excavated was 63.5 ft. in 48 months, and 8,500,000 cu. yd. were dredged. The best output of a single dredge for one month, working day and night, in soft soil, was 124,230 cu. yd. In hard soil a fair average was 90 cu. yd. per hr. The most suitable face against which to work was 6 ft. in height.

Ladder Dredge and Conveyor on N. Y. Barge Canal. *Engineering and Contracting*, Sept. 7, 1910, gives the following: The dredge was started on July 30, 1909, and worked 4 months of the season and was then laid up for the winter, as the canal is drained during the winter season. The costs given are for these 4 months' work. This dredging plant differs from other types in that the excavated material is carried by a series of belt conveyors to the spoil bank. The dredge itself is floated on two steel pontoons which are parallel to each other and are braced together by a rigid frame work. A gantry projects out in front and between these pontoons. This gantry supports the "ladder" or endless chain of buckets, which extends down between the pontoons to the bottom of the canal. The buckets move downward on the underside of the ladder and come up loaded and discharge into a hopper at the top. The buckets are each of 5 cu. ft. capacity. From the hopper at the top of the ladder the material is discharged onto a belt which in turn discharges into a second hopper and second belt at the rear of the dredge which projects out to the rear of the machine. A third belt is carried on a separate pontoon. It runs on a steel cantilever framework which carries the belt 40 or 50 ft. onto the canal bank. The pontoon which carries this belt is so arranged that it can be turned at any angle and still have its receiving hopper under the discharge of the second dredge belt. The belts are each operated by a separate motor receiving power from the dredge. The dredge plant cost $70,000. The plant took out from 20,000 to 32,000 cu. yd. per month during the first few months it was in operation in 1909, working three 8-hr. shifts per day.

The chief difficulty met with in the first part of the work was

holding the soft material in embankment. At first very heavy wooden forms were built to hold up the embankment to its full height. These proved very expensive and inefficient; they gave way in places and the soft material, which flowed out over the adjacent land, had to be scraped back. The plan now adopted is to build dikes of sod and earth about 4 ft. high along the outside edge of the embankment. The material is then deposited by the dredge within the dikes, the dredge moving along as soon as the material reaches the top of the dikes. When the material deposited has dried out sufficiently, a second series of dikes is built on top of the first and the dredge moved back to fill again.

The cost of the work for one season is given by months as follows:

August, 1909; 18,638 cu. yd. excavated:

Coal and oil	$1,984.50
15 tons coal for hoisting engine at $2.85	42.75
Misc. supplies for hoisting engine	5.25
Misc. supplies for hoisting engine and derrick	6.48
Hauling supplies	54.00
Crew of dredge	2,296.68
Total cost	$4,389.66
Cost per cu. yd. (ct.)	23.6

Drains and scrapers supplemented the dredge moving 6,244 yd. for a total of $1,280.50 or 20.5 ct. per cu. yd. The cost of wooden forms and of spreading and compacting amounted to $1,193 for 10,015 cu. yd. of embankment or 11.9 ct. per cu. yd.

September, 1909; 32,000 cu. yd. excavated:

Interest, depreciation and repairs	$2,205.00
180 tons at (2 tons per shift)	513.00
150 gal. gasoline at 12 ct.	48.00
Oil (80 gal. at 19 ct.; 60 gal. at 35 ct.)	36.20
1,200 lb. grease at 8 ct.	96.00
200 lb. waste at 8 ct.	16.00
Teams	245.00
Labor	2,827.00
Total cost	$5,956.20
Cost per cu. yd. (ct.)	18.6

A total of 90 (8-hr) shifts were worked. The cost of the embankment was as follows:

Labor spreading and compacting	$3,151.50
Hauling form lumber	177.16
Cost form lumber	1,125.00
General	290.00
Labor on forms	828.32
Hauling supplies	55.00
Total	$5,626.98

Only 11,000 cu. yd. were allowed for the above work on embankment as the forms gave way and the soft material had to be scraped back. This brought the cost of embankment for the month up to 51.1 ct. per yd.

October, 1909; 25,500 cu. yd. excavated:

Interest and depreciation	$2,351.66
186 tons coal at $2.85	530.10
Labor	3,145.58
Teams	5.00
Oil, grease and waste	153.09
Gasoline	18.60
Repairs	18.90
Total cost	$6,222.93
Cost per cu. yd. (ct.)	24.4

A total of 93 (8-hr.) shifts were worked. The cost of embankments was as follows:

Labor spreading and compacting	$2,898.25
Forms	567.50
Erection	108.50
Hauling	95.00
Total	$3,669.25

This gives for 21,800 cu. yd. of embankment a cost of 16.9 ct. per cu. yd.

Thomas J. Morrison objected that the cost shown for embankment in the foregoing paragraph was deceptive. It should be accompanied by an explanation, showing why it was so high. The embankment forms to hold the dredge material were very expensive, and the cost was charged up to the embankment on which they were built. Under the specifications, the embankment could not be estimated as paid for until finished; and the paid embankment was therefore only a small part of the excavations among which costs are given. For instance in November, the excavation was 20,560 cu. yd., of which only 513 cu. yd. were paid for in embankment. As a matter of fact, practically all of the material was placed into embankment that was not trimmed up, and was, therefore, not estimated. During the month following, all these unfinished embankments were dredged out at a cost of only a few cents per cu. yd., so that in the cost of forming embankments distributed over the entire work, instead of being separated into months was quite low. The cost for November was as follows: A total of 45 (8-hr.) shifts were worked; and 20,516 cu. yd. were excavated at the following cost.

Interest and depreciation	$1,102.50
Coal, 90 tons @ $2.85	256.50
Labor	1,437.80
Teams	00.00

Oil, grease and waste	$ 83.07
Gasoline	9.00
Repairs	94.50
Total	$3,383.37

This gives a cost for excavation of 16.5 ct. per yd. Labor on embankment was practically all for building dikes and cost $782.50. The number of cu. yd. for embankment estimated during the month was only 513, giving the cost per cu. yd. of $1.52.

A Record for Ladder Dredges. *Engineering and Contracting*, Jan. 18, 1911, reports that the Marmot of the Pacific Division, Panama Canal, a ladder dredge, broke all records for the daily, weekly and monthly output of ladder dredges in the Canal service during December. The output for the month was 219,795 cu. yd.; for the best week of 6 working days, 47,693 cu. yd., and for the best day (Dec. 14), 8,569 cu. yd. The output for the best 10-day period during the month was 77,838 cu. yd., or an average of 7,783 cu. yd. a day; for a 25-day period, 183,163 cu. yd. The average per working day over the whole month was 7,326 cu. yd. The above figures are based upon place measurement. The dredge was working the entire month in the approach channel to the site of the new docks at the Pacific entrance to the Canal, excavating earth to a depth of 31 ft. below low tide. The crew set deliberately to work on Dec. 1 to exceed all previous records, and by request of the men themselves, the dredge was kept at work every day in the month, excepting Christmas day. All the dredges work night and day. The best previous record for old French ladder dredges was made by the Atlantic Division dredge, No. 5, in July, 1909, which excavated 176,082 cu. yd.

Elevator Dredge Work on Sunnyside Irrigation Canal. In a long paper by Moritz and H. W. Elder, in *Engineering and Contracting*, Sept. 11, 1912, the description and cost of elevator dredge work on the enlargement and improvement of the Main Canal of Sunnyside Yakima Project at Washington, is given. A floating dredge was used upon the first 21 miles. As the concrete lock structures, of which there were about 18, had a clearance of only 32 ft. between the walls, and as the dredge had to pass through these, the hull could be only about 30 ft. wide. This reduced the stability of the machine considerably. It would have been much easier to handle if it had had a wider hull. The machine used was a 3.5 cu. ft. steam driven continuous bucket, elevator type, with an 82 x 30 x 6.5-ft. hull, drawing 5 ft. of water. The steam was furnished by two 80-hp. locomotive type boilers, 44-in. by 18-ft. The main drive and ladder hoist was driven by a 70-hp., 8 x 12-in. double horizontal engine. Machinery for spuds and for swinging was driven by a 2 cylinder,

20-hp., 6 by 6-in. double horizontal engine. The conveyers were driven by two 18-hp., 7 by 10-in. single cylinder horizontal engines. A no. 1 hydraulic giant, supplied by a 2-stage, 6-in. centrifugal pump, belted to an 80-hp., 10 by 12-in. single cylinder upright engine, was mounted in the bow, to remove the bank beyond the reach of the bucket above the water level. The conveyors were 72 ft. long and had 32-in. rubber conveyor belts. This machine was operated from Dec. 4, 1909, to Oct. 1, 1911, and removed 921,000 cu. yd. of material.

Had the running water been of sufficient depth at all times in the canal, much unnecessary excavation would have been saved; for the machine excavated in some cases 4 ft. below grade, in

Fig. 8. Bucket Elevator Dredge, Sunnyside Canal.

order to have sufficient water to float. A great deal of difficulty was encountered in disposing of excavated material. So much water was carried over with the earth and gravel, that a mud was formed, which ran out into the adjoining field orchard, covering the original ground to a depth of several feet. Bulkheads had been built in an attempt to hold the material. This was found very expensive, so finally ¾-in. holes were bored in each bucket, to allow the water which was picked up with the dirt to escape. This accomplished a great deal toward retaining the material on the right-of-way.

The statement of cost given below requires some explanation. The labor cost is low. The high cost charge to the item spoil bank is due to the fact that much of the material was deposited in the form of muck that ran over valuable farm land; and had to be hauled back when dry, unless it had been retained by the expensive bulkhead along the right-of-way. Another reason for the high cost of this item, is that much of the material was

deposited in high mounds, which had to be graded down to permit ditch riders to travel over the levee. The high cost of maintenance was due to the fact that much adjusting and many changes had to be made to adapt the machine to local conditions. The depreciation item includes the entire cost of the machine ($41,400), charging it against the total yardage. Everything except the hull should have considerable salvage value, which will go toward reducing the cost. Fuel had to be hauled about 3 miles across open country or over roads that were very rough.

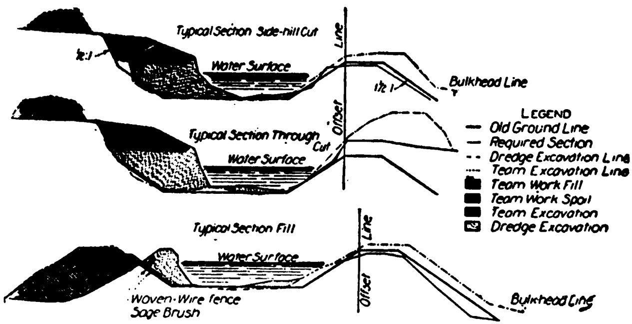


Fig. 9. Typical Sections Excavated by Elevator Dredge.

The most gratifying result of this work was the solid lower bank produced by the saturated material discharged by the dredge, and the substantial roadway over it. The cost of 920,723 cu. yd. was:

	Per cu. yd.
Labor, dredge	$0.029
Labor, spoil banks	0.034
Fuel	0.036
Plant maintenance	0.057
Plant depreciation	0.045
Total per cu. yd.	$0.201

Miscellaneous. Maximum excavation per 8-hr. shift, 1,429 cu. yd.; maximum excavation for one week, 17,644 cu. yd. (three shifts); average excavation per 8-hr. shift, 557.9 cu. yd.; average excavation actual working hr., 128.7 cu. yd.; per cent. of lost time, 49; made up as follows: moving, 10%; repairs and miscellaneous, 39%.

Force and Wages. An operating force consisted of 8 men and 4 horses.

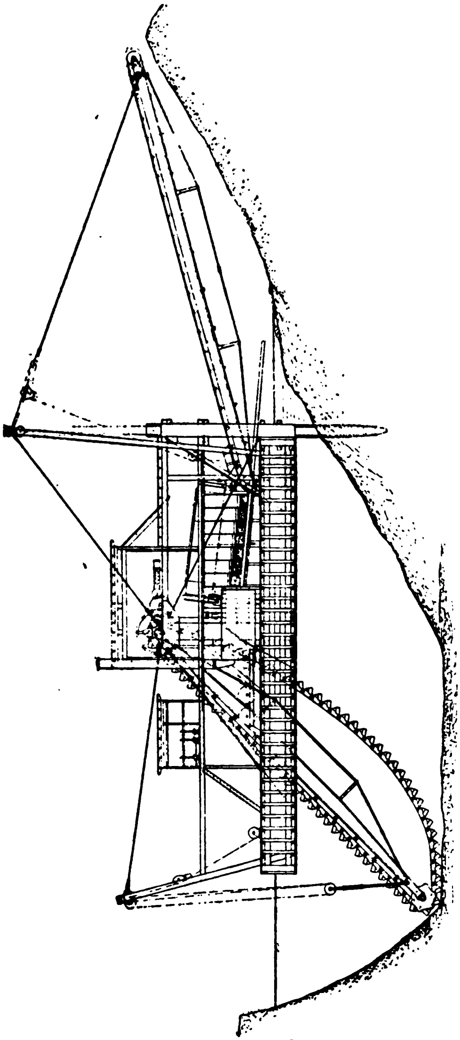


Fig. 10. Side Elevation of Steam Driven Placer Mining Elevator Dredge Made by the Marion Steam Shovel Co.

Wages paid were: Operator, $5.00; engineer, $4.67; spudman, $3.83; fireman, $3.33; oiler, $3.00; deckman, $2.50; man and team, $4.50.

Gold Dredging. In the bibliography at the end of this chapter will be found many references to articles on gold dredging. The elevator dredge is used almost exclusively for this class of work, so that any one who desires all the information available on this type of dredge should study the articles on gold dredging. Partly because these machines are too highly specialized to be of direct interest to the average earth excavator and partly because elimination in an almost endless field of information is necessary, gold dredging will not be discussed in this volume.

Operating Cost of a Hydraulic Dredge. J. M. Allen, in *Engineering News*, Oct. 29, 1914, gives the following: The tabulation gives the typical operating costs of a 15-in. hydraulic dredge on the Mississippi River, in 1914, working two 12-hr. shifts. Wages do not include subsistence. Assuming an output of 75,000 cu. yd. per month, the cost is about 6 ct. per yd.

1 foreman	$ 150
1 engineman	125
1 engineman	100
2 suction operators, at $100	200
2 oilers, at $60	120
2 firemen, at $70	140
2 coal passers, at $60	120
3 deck hands, at $60	180
1 levee foreman (day)	90
1 levee foreman (night)	70
10 levee laborers, at $60	600
26 Total labor cost per month	$1,895
Coal (18 tons per day)	1,200
Supplies (rope, oil, packing)	150
Repairs and renewals	200
Office and over head expenses	200
Insurance (fire and liability)	100
Interest and depreciation (2% on $35,000)	700
Total operating cost per month	$4,445

Hydraulic or Suction Dredges. There are four general classes of this type of dredge: (1) The seagoing hopper type without anchorage; (2) the lateral feeding type, with 5 or 6 mooring lines to anchors, for use in wide channels; (3) the forward feeding type with one or two forward mooring lines to anchors; (4) the radial feeding type with spud anchorage. Hydraulic dredges may also be classed thus: (1) Plain suction pipe dredges; (2) with water jet agitators; (3) with mechanical agitators or cutters. Cutters are generally necessary for material other than sand.

The forward feeding type of dredge is adapted to work in

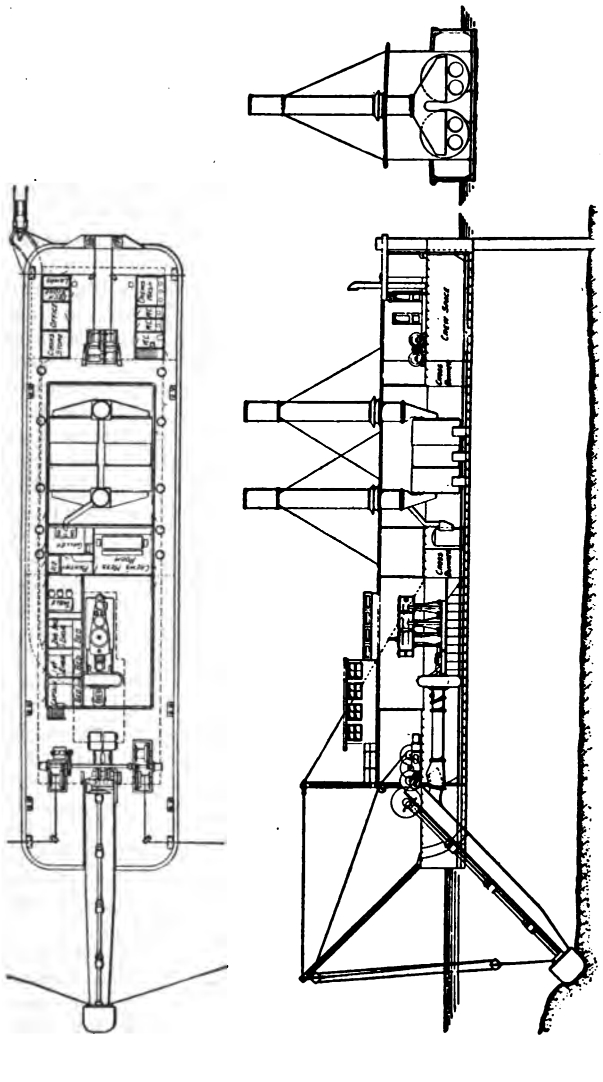


Fig. 11. Radial Feeding Type Hydraulic Dredge Made by Theodore P. Smith and Sons Co., Jersey City, N. J.

shallow alluvial rivers such as the Mississippi, and for this reason it is often called the Mississippi type dredge. Almost all of the work on the Mississippi River is done by the government. The Alpha was the first dredge of this type built for the Mississippi River Commission. This was followed by the Beta and Gàmma.

The radial feeding type of suction dredge is usually anchored by one or more spuds, the suction pipe making a radial cut on the arc of a circle about the spud as a center. This is the common type of dredge for general work.

The seagoing type is confined to harbor work, and the forward feeding type is used on alluvial rivers.

The Floating Pipe Line. The pipe line of a dredge is generally built of thin sheet steel. Almost any kind of floats are used in quiet waters. In exposed situations the pipe and floats are built of heavy material, solidly constructed. A water velocity of 7 ft. per sec. in clay or mud, or of 10 ft. in sand generally gives good results. For moderate distances velocities of 12 to 16 ft. per sec. are sometimes employed. The percentage of solids varies up to 75%. It is less difficult to transport a large percentage of solid material after it has entered the pipe line than to introduce it into the pipe without choking the pump. At Oakland, California, a dredge belonging to the Atlantic Gulf and Pacific Company delivered material through 6,170 ft. of 20-in. pipe. Other dredges built by this company for the Baltimore Water Works pumped through pipe lines 10,800 ft. long, but part of this line was down grade giving a 10 ft. negative ahead.

The Output and Cost of Operation. This varies widely. In the centrifugal type the construction of the dredge itself has a large influence upon the cost of operation and repairs. The type of pump selected is particularly important. The side suction type gives an easier passage through the larger bends and is therefore generally preferred, but the double suction type of pump avoids side thrust. The shape of the pump and vanes also has a material effect upon its wearing qualities. A badly designed pump, especially when excavating sharp sand, will wear out in a very short time. The mooring and dredging moving equipment, and the digging, cutting, or agitating appliances are also of the greatest importance.

Robert A. Cummings, in *Transactions American Society of Civil Engineers*, vol. 31, 1894, states that with centrifugal pumps for silt and alluvial deposit 30 to 40% of solids, and for coarse gravel and fine sand 10% of solids is the best proportion of the volume pumped.

It is stated in *Engineering News*, Dec. 15, 1898, that with the

12-in. dredge the discharged material ordinarily consisted of about 10% of solid matter. At times, however, the 1,000 ft. of discharge pipe would start to clog up, but by increasing the speed of the pump the material was forced out in a nearly solid mass that would break off in lengths of 15 to 18 in.

The water in which the dredge worked was furnished from a source 1,700 ft. distant by a 12-in. pump through a 6-in. discharge pipe. The soil was clay naturally wet and soft because of seepage water and therefore unfavorable to dry excavation methods, but decidedly favorable to hydraulic dredge work.

Depth at Which Suction Dredges Can Work. The *Engineering and Mining Journal*, Nov. 7, 1914, describes a dredge made for the Calumet and Heckla Mining Co. for use in working over stamp mill tailings in Torch Lake, Mich. This dredge is equipped with two 20-in. centrifugal pumps, one driven by a 750-hp. motor, and the other by a 1,250-hp. motor. Previous to the construction of this dredge the greatest depth attained by suction dredge was 70 ft., which depth has been reached by the sand suckers working in Long Island Sound. The Calumet and Heckla dredge is intended to dig to a depth of 100 ft.

Dredging in Mobile Harbor, Alabama. *Engineering and Contracting*, Mar. 20, 1912, gives the following: Three types of dredges have been employed in improving and deepening the ship channels in and about Mobile Harbor. These are the clam shell, the seagoing suction and the hydraulic pipe line. In an article in *Professional Memoirs* for March-April, 1912, Assistant Engineer J. M. Pratt describes the work of these dredges. A comparison of output and cost is made between a clam shell and a hydraulic dredge. Records of work are given of one seagoing hopper dredge and three hydraulic pipe line dredges, including costs and statement of delays. Structural defects and advantages of the dredges are specified.

Comparison of Clam Shell and Pipe Line Dredge. The Mobile Harbor dredged channel extends from Chickasaw Creek, 4.8 miles above the mouth of Mobile River, to deep water in the lower portion of Mobile Bay, a total distance of 33½ miles. The material along the upper six miles of this channel consists principally of sand and clay with some mud. Along the next eleven miles it is mud and sand with strata of shells at the lower portion. The material along the remainder of the channel is composed of a soft blue mud having a specific gravity, as it lies on the bottom, of about 1.36. From the head of the channel in Mobile River to a point ten miles below, the dredged material either has to be deposited on shore or towed several miles in scows, because the water on the edges of the channel is too shoal

for loaded scows to get out. A dredge would be protected from storms, unless of unusual severity, while working in the channel in Mobile River, and be better protected while working in the upper portion of Mobile Bay than in the lower portion, thus making delays in dredging on account of weather conditions much less in the upper than in the lower bay and reducing them to a minimum in the river. All of these considerations make it difficult to form a comparison between two dredges working in this channel, unless engaged near the same locality at the same time. However, a fairly good comparison may be obtained of a clam shell and a hydraulic pipe line dredge by taking the records made in 1909 by the clam shell dredge *A* and the hydraulic dredge *B*, both belonging to contractors and working under the same contract a few miles apart in middle and lower Mobile Bay. The yardage dredged represents the amount excavated from the theoretical section in either case, or the amount paid for and not the total amount removed. The time extends from April 1 to July 12, the hydraulic dredge working two days longer in July than the clam shell, which discontinued work on the 10th. The material in each case was mud, although that obtained by dredge *A* was much softer and more easily handled than where the hydraulic dredge was working during April and May. In June this dredge reached a point near where dredge *A* had been working, and her results were largely increased. These dredges are both representative of their respective types and the material was deposited by each about 1,200 to 1,500 ft. from the channel. Dredge *A* has an 8½-cu. yd. clam shell bucket and dredge *B* has a 20-in. centrifugal pump with a 22-in. suction and 20-in. diameter discharge. The following table shows the amount dredged per month and the delays to each dredge.

Month	Cu. yd.	Time lost Hr.
Dredge A.		
April 1 to 30	208,922	157
May 1 to 31	195,231	179
June 1 to 30	155,016	173
July 1 to 10	70,567	56
Total	629,736	565
Dredge B.		
April 1 to 30	226,294	114
May 1 to 31	244,350	161
June 1 to 30	410,821	67
July 1 to 12	142,576	44
Total	1,024,041	386

The time lost in each case does not include Sundays or legal holidays, but is a portion of the total effective working time.

This work was done at a contract price of 9.95 ct. per cu. yd., but during the last two contracts work has been done at this locality for a little less than 6 ct. per cu. yd. Figuring on this basis and estimating the value of each outfit to be: $75,000 for dredge *A* and attendant plant, and $125,000 for dredge *B* and attendant plant, the value of each in earning power is as follows:

Dredge A

629,736 cu. yd. dredged, at 6 ct.		$37,784
Interest on $75,000 for 3⅓ months, at 6%	$ 1,250	
Depreciation at 10% per annum, for 3⅓ months	2,083	
Cost of operating dredge, 3⅓ months	14,300	
		17,633
Amount earned		$20,151

Dredge B

1,024,041 cu. yd. dredged, at 6 ct.		$61,442
Interest on $125,000 for 3⅓ months at 6%	$ 2,083	
Depreciation at 10% per annum, for 3⅓ months	3,472	
Cost of operating dredge, 3⅓ months	28,333	
		33,888
Amount earned		$27,554

Thus, in a little over three months, the hydraulic dredge earned about $7,500 more than the clam shell dredge, though the latter was one of the best ever seen in this district. The hydraulic dredge experienced fewer delays in general, and could work as long during rough weather as the clam shell dredge, the latter, of course, having to quit work when it became too rough to land scows alongside.

Mr. Pratt describes an interesting expedient resorted to to remedy a difficulty encountered with the Seagoing Hopper Dredge Charleston which decreased its output in very soft mud. It was found that when the drag was lowered below the surface of the material that it buried in the mud, the pipe would continually choke, and the drag would then have to be lifted in order to admit sufficient water to clear it. This, of course, would put a great deal of water in the bins which could not be disposed of, and simply decreased the amount of material carried at each load. If the drag were kept near enough to the surface of the material to prevent choking, a large percentage of water was admitted, and the result was practically the same. The only way then to obtain a maximum amount of material in the shortest time was to bury the drag below the surface of the material, move slowly along the cut as before, and admit just enough water in the drag to pump the material without choking it or having to raise the drag. This was accomplished by cutting a hole in the top of the drag and fastening thereon a pipe (Fig. 12), 5⅜ in. in diameter and 12 ft. long, which ex-

tended up the outside of the main suction pipe and was fastened thereto. A valve was placed in the upper end of this 5⅜-in. pipe, as this was always above the surface of the material on the bottom, and just enough water admitted to enable the pump to work properly. When shifting the dredge from this locality to the other bar, this pipe was removed and a steel plate put in its place, filling up the hole in the drag. The value of this pipe to the dredge when working in very soft material may be seen from the fact that before installing this pipe the average time required to load 200 cu. yd. was 49 min., and after the installation only 25 min. were required.

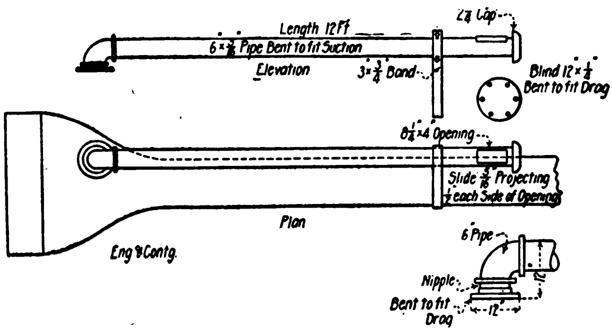


Fig. 12. Improved Suction Pipe for Seagoing Hopper Dredge Charleston.

Dredging Ocean Bars. The following data relative to work done at various harbors by three government dredges, have been abstracted from a paper by Major J. C. Sanford in *Transactions American Society of Civil Engineers*, vol. 54, part C, 1905.

The following are monthly reports for July, 1904, of the Gedney, working at New York Harbor; the Gen. C. B. Comstock, working at Galveston, Tex., and the Sabine working on the bar outside the mouth of South Pass, Mississippi River. These may be taken as typical of the work of the older and smaller class of dredges under rather favorable conditions.

DREDGE GEDNEY

Location of work, north side of Gedney Channel, New York harbor

Depth of water (survey of Jan., 1904)	27 to 30 ft. M. L. W.
Depth required	30 ft. M. L. W.
Range of tide	4.6 ft.
Material dredged	Sand and gravel in varying proportions
Cubic yards removed	53,193
Loads	88

Yards carried per load, average	604
" dredged per minute, average	15.0
Time dredging	59 hr. 14 min.
" turning	2 " 37 "
" running to dumping ground	53 " 48 "
Average speed, loaded	5.4 knots
Time running from dump to working ground	32 hr. 11 min.
" " " " " anchorage	18 " 24 "
" " " " " wharf	18 " 02 "
" " " anchorage to working ground	12 " 59 "
" " " wharf to working ground	12 " 29 "
" " " anchorage to anchorage	1 " 12 "
" lost repairing (while under steam)	1 " 06 "
" lost from other causes (while under steam)	05 "
" dumping	11 " 45 "
Average time dumping per load	8 min.
Total time under steam	223 hr. 47 min.
Average speed, light	6.9 knots
" " " (to and from wharf)	7.4 "
Approximate speed while dredging	1.5 "
Time lost due to fog	1¼ days
" " " " rough sea	½ "
" " " " repairs	¾ "
" " " " coaling ship	2½ "
" " " " other causes	½ "
" actually working	19½ "
Distance from working grounds to dumping grounds, mean	3.3 nautical miles
Coal burned (pea coal)	207 long tons
Water used	35,300 gal.

Average cost of dredging per cu. yd. (based on actual cost of coal, water, rent of wharf, wages of crew, and mess bills, and on average of ten years' cost, per working day, of repairs and supplies). 5.9 ct.

DREDGE GEN. C. B. COMSTOCK

Quantity of material dredged	67,476 cu. yd.
Character of material dredged	Sand, mud and clay

Distribution of working time:

Anchorage to cut	9 hr. 55 min.
Pumping	147 " 29 "
Cut to dump	33 " 35 "
Dumping	8 " 10 "
Dump to cut	25 " 27 "
Dump to anchorage	10 " 10 "
Time lost turning	0 " 00 "
Total hours worked	234 hr. 46 min.

Time lost on account of bad weather, Sundays and holidays, washing out boilers and repairs	220 hr. 37 min.
Cost of operating for the month	$2,888
Cost of extraordinary repairs for the month	774

Fuel consumed, 845 bbl. fuel oil at 70 and 75 ct. per bbl.

The dredge Sabine was transferred on July 13, 1904, for work beyond the ends of the jetties at South Pass. The dredge left New Orleans on July 14, arrived at Port Eods on July 15, and began work beyond the ends of the jetties on the same day. The material removed consists principally of a stiff clay or mud, with some sand. Between July 15 and 30, the dredge worked 161.5 hr., distributed as follows:

Moving to and from dredging position	13 hr.
Pumping	102 "
Dumping	28 "
Repairs	12½ "
Taking aboard fuel	6 "

During this time the dredge removed 286 loads of material containing a total of about 55,770 cu. yd. of solid matter. The expenses of the dredge from July 13 to 31, were about $1,250, making the average cost per cu. yd. of material removed about 2¼ ct. From the 13th to 31st, 439 bbl. of fuel oil were consumed, of which 401 bbl. were used in connection with the dredging operations proper. In August, 1904, this dredge removed 67,860 cu. yd. at this locality, the average cost for working expenses being 3 ct. per cu. yd.

Work of Hopper Dredges in Ambrose Channel. Two dredges, "Thomas" and "Mills" were constructed after the "Liverpool type" of dredges for the Metropolitan Dredging Co., to work in New York Harbor. These dredges were each self-propelling steamers of 7,000 tons displacement, 300 ft. long, 52.5 ft. beam, with a hopper capacity of 2,800 cu. yd., and a speed of 10 knots. The draft when empty was 13 ft., and when loaded 18 ft. Each was equipped with a double-suction, 48-in., centrifugal pump. The suction pipe was 48-in. diameter, and operated through a longitudinal well in the vessel. The hoppers or bins were dumped through bottom valves. The cost of each dredge was about $475,000.

At work in New York Harbor, sand (70%), with clay (5%), gravel and small stones was the material dredged. The sand fed freely. The maximum rates of loading were as follows: 2,850 cu. yd. in 32 min.; 21,624 cu. yd. in 1 day; 285,551 cu. yd. for one dredge in 1 month; 552,297 cu. yd. for both dredges in 1 month. During the 12 months ending June 30, 1902, the two dredges removed 5,015,568 cu. yd. of sand, of which 923,176 cu. yd., or 18.4%, were from below the required depth, leaving a net output of 4,092,392 cu. yd., or 170,516 cu. yd. per month per dredge.

The large amount cut from below grade was due to the method of working the Liverpool type of dredges. The vessel was anchored while dredging and thus deep holes with intervening high ridges resulted. It required from 3 to 6 moves to obtain a full load. Naturally an uneven bottom was left.

During 562 working days previous to May 31, 442 (78.7%) days were actually worked, 88 days (15.7%) were used for repairing, and 32 days (5.6%) were lost during bad weather. During the working days, 15¼ hr. per day were worked, the re-

mainder of the time being charged to weather, coaling, minor repairs, and lack of steam.

The time occupied in pumping, removing and dumping an average load of 2,500 cu. yd. was 3 hr. 50 min., of which 1 hr. 45 min. was spent in going to and returning from the dump (12 miles), and 15 min. in dumping.

The crew required for day and night work on each dredge was 54 men; the monthly payroll was $2,700 per dredge.

Work of U. S. Dredges in Ambrose Channel. Henry N. Babcock, in *Engineering and Contracting*, Oct. 3, 1906, gives the following: The two dredges "Manhattan" and "Atlantic" differ essentially in their method of operation from the Liverpool type of dredge described in the last paragraph. The Liverpool type of dredges dredged while stationary, and thereby sunk holes to great depths. The ridges between these holes did not wash away to the extent that might be expected. This was due to the nature of the sand, which varied from medium fine to coarse, was hard packed and possessed much stability. Dredges of this type were successful at Liverpool, England, where the bottom is a fine quicksand which ran into deep holes as soon as they were made.

To overcome this defect the government vessels were designed to dredge while proceeding at low speed, thus removing a strip of approximately constant depth from the channel bottom. The following relates to the work of these dredges during their first season.

These vessels were of the same plan, each being steel, twin-screw steamers, 288 ft. long, 48 ft. wide, with two self-contained sand-bins, holding about 2,300 cu. yd. when fully loaded. Each dredge was equipped with two 20-in. centrifugal pumps, 20-in. suction pipes, and 4 boilers each 14 ft. diameter by 12 ft. long.

After certain trials, the dredges "Manhattan" and "Atlantic" began actual work at Ambrose Channel on Feb. 8, 1905. The material was excavated to a depth of 40 ft. It consisted mainly of coarse and fine sand and gravel, a small amount of clay, some mud, and about 3% of miscellaneous refuse such as paving blocks, timber, iron, chain, etc.

Each dredge had two drags, which made two furrows each 5 ft. wide, 3 or 4 in. deep, and about 52 ft. apart. With the vessel proceeding at speeds of 1.5 to 3 miles per hr., a load of 2,200 cu. yd. (about 1,800 cu. yd. place measure) was removed in a length of 15,000 to 20,000 ft. The courses were laid out so that a dredge obtained a full load in going up and back once.

The distance to the dumping grounds was about 8 miles. The

average time going loaded was 46 min., and returning empty 36 min., a total of 82 min. (or 28% of total working time) for an average load of 2,044 cu. yd. Up to Aug., 1905, dredging was performed during the day, but since that time both day and night. Night work is about 90% as efficient as day work.

Up to July 1, 1905, the dredges were undergoing many alterations and repairs. During 8 months' work of one dredge and 2 months' work of the other 467,450 cu. yd. (46,745 cu. yd. per dredge month) were removed at a cost of 9.9 ct. per cu. yd. From July 1, 1905, to May 31, 1906, both dredges, working 11 months each, removed 3,258,707 cu. yd. at a "field" cost of 5.3 ct. per cu. yd. The itemized cost was as follows:

	Ct. per cu. yd.
Pumping	3.357
Turning	0.206
Going loaded	0.835
Dumping	0.223
Returning empty	0.653
Total per cu. yd.	5.274

It will be noticed that about one-third of the total working time is spent in travelling and dumping the load.

Divided according to items of expense, the cost was as follows:

	Ct. per cu. yd.
Payroll	1.761
Coal	1.408
Water	0.039
Subsistence	0.476
Engine-room supplies	0.098
Miscellaneous supplies	0.150
Repairs and renewals	1.342
Total per cu. yd.	5.274

These vessels are very sea-worthy and remain at work as long as it is possible to dump at sea. The week's work begins at 5 A. M. Monday, when they leave their docks. At noon Saturday they return to dock and that night or on Sunday they take on coal and supplies, clean boilers, etc. During the period, July 1, 1905, to May 31, 1906, out of 670 days of 24 hr. each, 335.1 days (50%) were spent actually at work, 138.1 days (20.6%) were lost while repairing, 11.5 days (1.7%) on account of fog and snow, 13.4 days (2.0%) on account of storms, 46 days (6.9%) while taking on coal, in making minor repairs, etc., 3.7 days (0.6%) on account of miscellaneous delays, 12.2 days (1.8%) in July before night work began, and 110 days (16.4%) on Sundays and holidays.

The estimated total cost of work of one dredge for one month is given below. The unit cost is based on the average monthly output of one dredge during the twelve months ending June 30, 1906, of 158,100 cu. yd. During June, 1906, the two dredges excavated 535,692 cu. yd. (267,846 cu. yd. each). The crew required on each dredge numbers 54 men, the wages paid being as follows:

Deck:	
1 engineer inspector	$ 166.66
1 master	175.00
1 mate	120.00
1 mate	90.00
1 mate	75.00
3 dredgemen at $40	120.00
4 dredgemen at $30	120.00
6 deckhands at $35	210.00
7 deckhands at $30	210.00
Engine Room:	
1 chief engineman	150.00
1 assistant engineman	110.00
1 assistant engineman	90.00
1 assistant engineman	75.00
9 oilers at $45	405.00
9 stokers at $40	360.00
Steward's Department:	
1 cook	60.00
1 cook	45.00
1 cook	30.00
3 waiters at $20	60.00
Carpenters:	
1 (½ time to each dredge) at $60	30.00
Total	$2,701.66

The actual pay roll has varied from $2,406 to $2,709, the average being about $2,660. The deck crew works 12 hr. per day while dredging and 8 hr. per day while repairing. The engine room men and the computers work 8 hr. per day. The fuel used is free burning bituminous coal, purchased under different contracts at prices ranging from $3.01 to $3.25 per ton of 2,240 lb.

	Per month
Payroll	$ 2,660
Coal	2,480
Water	60
Subsistence	700
Engine-room supplies	150
Other supplies	250
Casual repairs	500
Total operating expenses	$ 6,800
Docking, painting — 2 times per year	$ 1,250
Renewals of equipment, per year	12,150
Miscellaneous, per year	1,000
Total maintenance per year	$14,400
Total maintenance per month	$ 1,200
Depreciation fund, 10% on $341,800	$34,180
Interest at 4%	13,672
Insurance at 2%	6,836
Total fixed charges per year	$54,688
Total fixed charges per month	$ 4,500
Grand total per month	$12,500

Note that the rate of interest is very low. Also note that the dredge is assumed to work 12 months every year, which is usually unattainable over a long period of years.

The field cost of dredging already stated was 5.27 ct. per cu. yd. The cost of interest, depreciation, and insurance ($4,500) divided by the average monthly output of 158,100 cu. yd., gives a further charge of 2.85 ct. per cu. yd., which brings the total cost of dredging to 8.12 ct. per cu. yd., which is slightly less than the price bid by a contractor of 9 ct. per cu. yd. It should be noted that the cost of repairs is probably less than the cost of repairs on an older boat.

In *Professional Memoirs*, January–March, 1909, Capt. H. L. Wigmore gives further cost data of the work of the *Manhattan* for 1908 in Ambrose channel. This article was abstracted in *Engineering and Contracting*, Sept. 22, 1909. Below is given cost of operating the *Manhattan*, with further data showing the cost to a contractor and to the government. In calculating the cost to a contractor the cost of surveys and examinations should not be considered, but the cost of interest, depreciation, and insurance should be. All of these items, except interest and insurance, should be included in an estimate of the cost to the government.

Pay roll	$31,891.63
Coal	34,820.06
Subsistence	12,390.46
Supplies	4,704.84
General repairs	20,369.61
Wharfage	777.50
Total	$103,954.10

The total yardage of the "Manhattan" for the period from June 30, 1907, to June 30, 1908, was 2,660,513 yd. Taking the total cost of operation as $103,954.10, which includes all items of expense which would be borne by a contractor, we have a cost per yd. of	$0.039
Building cost of "Manhattan" was $340,041.58.	
Ten per cent. sinking fund, $34,004.16 = per yd.	.013
Insurance and interest taken at 7%, $20,802.91 = per yd.	0.008
Cost to a contractor	$0.060
There should be added an allowance of 12½% in this case for over depth in dredging for which the contractor is not paid = per yd.	.006
Total	$0.066
Total cost to the United States was as follows (excepting cost of vessel):	
For cost surveys and examinations for two boats $19,983.34 or $9,991.67, chargeable to the "Manhattan"— per cu. yd.	$0.004

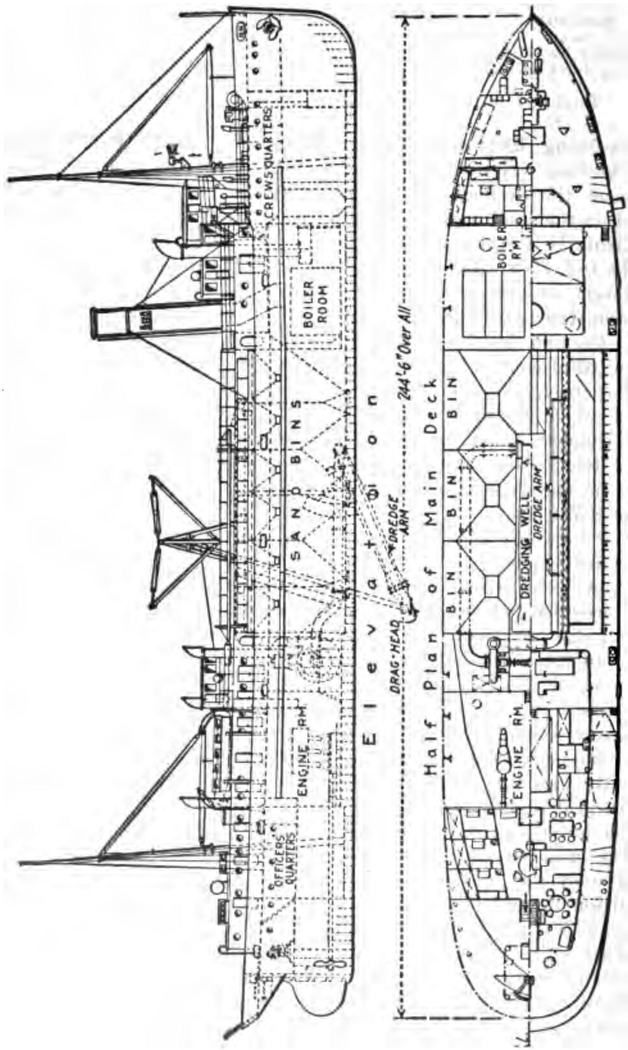
For office and contingent expenses $6,752.15. $3,376,075 for the "Manhattan." To this should be added $1,500 for the inspector's salary — per cu. yd.	.002
Operating as before — per cu. yd.	.039
Sinking fund as before — per cu. yd.	.013
Total cost to the United States	$0.058

Sea-Going Hydraulic Hopper Dredge for North Pacific Bars. *Engineering News-Record*, Nov. 8, 1917, describes a dredge built to meet the extreme conditions of digging and seaway encountered on the sand bars of the river entrances of the North Pacific, particularly at Coos Bay, Oregon.

The *Col. P. S. Michie* was designed in the office of the chief of engineers and placed in commission in the spring of 1914. She was constructed in the yards of the Seattle Construction and Dry Dock Co. and delivered ready for service in 16 months from date of award of contract, at a cost of $378,198. The dredge is of steel construction, has a length of 244.6 ft. over-all, molded amidship width of 20 ft.; draft, light, of 11 ft., draft, loaded, of 17 ft.; displacement, light, of 1,708 tons and displacement, loaded, of 3,372 tons. Her speed, light, is 10 knots and loaded 8 knots, and the speed maintained while in operation is 1½ knots; engines, 1,780 hp.

There are six bins, three on each side of the well, having a combined capacity of 1,400 cu. yd. These bins are fitted with overflow weirs which dispose of all surplus water. Openings are also provided below the level of the maximum capacity to permit the dredge to operate on a lighter draft if necessity demands. A trap gate in the bottom of the bins releases the material. The bins can be filled or dumped with dredges singly, collectively or in pairs. In order to keep the vessel from listing, especially in heavy seas, it is the practice to empty partly the two forward hoppers, then to dump the four after hoppers. The dredge actually fills the hoppers in 45 min. and it is able to dump its entire load in 7 min.

The lower end of the dredge arm is fitted with a drag head of the usual type used by sea-going dredges. The first drag head used was made of ordinary steel and was in serviceable condition for about 30 days of actual use. A new drag made of manganese steel has seen two years of actual service and has handled as many as 27 cu. yd. of material per min. over long periods of operation. The dredge arm has been operated in 42 ft. depth of water and in this position has an angle of 30° from the vertical. All movements of the dredge arm, pumping, disposing of material, etc., are mechanically operated, the chief operator's



Half Plan of Lower Deck & Hold

Fig. 13. Sea-Going Hydraulic Hopper Dredge *Michie.*

station being located conveniently to afford a clear view of all movements.

When dredging operations began in 1914 there was 17 ft. of water on the bar. The following is a record of the first season's work of the *Michie.*

The unit cost of dredging for the season was 14.6 ct. per cu. yd., of which the labor cost = 6.8 ct. per cu. yd. and fuel oil = 3.1 ct. per cu. yd. The pumping average for the season was 14.5 cu. yd. per min.

The cost of dredging for the season of 1915 was 5.13 ct. per cu. yd., of which the labor cost was 1.95 ct. per cu. yd. and fuel oil 1.6 ct. per cu. yd. Operations for the month of March give a record well worthy of consideration. This month the cost of dredging was 2.88 ct. per cu. yd. The costs given include all overhead expenses, including a 2% charge for Portland office expenses, but do not include the expenses incurred by the dredge while out of commission.

Filling Behind Bulkheads. The cost of dredging by Seattle and Lake West Waterway Company is given by C. H. Rollins in a paper read before the Pacific Northwestern Society of Engineers, May, 1904.

Dredging was performed by a Bowers pattern dredge, filling behind bulkheads of brush and dikes of sand with straw or hay embedded in them. The outlet for the waste water was through vertical sluice boxes from the bottom of which other horizontal boxes extended to a point beyond the fill. Other bulkheads were of piles and planking. The brush bulkheads were the best for they were semi-permanent. Brush bulkheads were in good condition after being in place 9 years.

Brush bulkheads were constructed as follows: Young fir brush was so placed with the butts out as to give a slope of 1 or 1½ to 1 to the face. The top width of the bulkhead was 12 ft. Piles were driven in 2 rows 10 ft. apart, piles being 6 or more ft. apart on centers. Planks were temporarily spiked to the piles to hold the brush in place. The brush was kept a little above the fill at all times. This type of bulkhead permitted the water to waste rapidly but held nearly all of the filling material.

Temporary Pile and Plank Bulkheads were constructed by driving piles in 2 rows, 8 to 10 ft. apart, with piles at 8-ft. centers. The outer row of piles was braced with 1½-in. planks to the inner row, and the inner row was braced with planks to anchors in the fill. Planks were spiked to the inside of the outer row of piles for half their height, and to the inner row of piles for the remainder of the height of the fill. The planks were

1½ in. (or occasionally 3 in.) thick. This type of bulkhead was inexpensive and satisfactory.

The dredging was performed by two 20-in. suction dredges. The *San Diego* was equipped with a 600-hp. engine and a rotary cutter, and could dig to over 50 ft. in depth. The 30-in. discharge line was supported at the shore and by tackles from derrick scows. The *Portland* was equipped with 800-hp. engine and 22-in. discharge.

Hydraulic Dredging at Oakland Harbor, Cal. L. J. Le Conte in *Transactions, American Society of Civil Engineers*, Vol. 13 (1884) gives the cost of dredging with a hydraulic dredge. This machine was equipped with a rotary cutter for work in hard material, 20-in. suction pipe, a centrifugal pump, two 16 x 20-in. pump engines, two 12 x 12-in. cutter, hoist, and winch engines, and two 100-hp. boilers. The material excavated was sticky, blue clayey mud. The percentage of solid matter discharged from the pipe line varied up to 40%; the advisable maximum percentage was 15%.

During the years 1883 to 1886 inclusive, in 23 working months, 1,201,370 cu. yd. were excavated, an average of 52,233 cu. yd. per month. The length of the discharge pipe line varied from 900 to 3,900 ft. The maximum monthly output was during Oct., 1885, when 85,902 cu. yd. were discharged in 269 engine-hr., through 3,400 ft. of pipe line. In Apr., 1884, 63,080 cu. yd. were discharged in 275 engine-hr. through 3,900 ft. of pipe.

The monthly expenses were as follows:

	Per month
1 captain	$ 200.00
1 engineman	100.00
2 firemen at $60	120.00
1 mate	60.00
2 guy-tenders at $40	80.00
3 deckhands at $40	120.00
1 cook	60.00
Board for 11 men at $15	165.00
Coal, 62.5 tons at $9	562.50
Oil, 25 gallons at $1	25.00
Water, 1,500 gal. at 1 ct.	15.00
Repairs to dredge and pipe line	300.00
Interest on plant, $50,000	300.00
Depreciation	208.50
Insurance	167.00
Taxes	50.00
6 shore men at $60	360.00
52,233 cu. yd. at 5.5 ct.	$2,893.00

Hydraulic Dredging at Rockaway, N. Y. *Engineering Record*, Sept. 22, 1900, contains a description of an embankment between Brooklyn and Rockaway, New York City, which was formed of hydraulic dredged material. The embankment was 70 ft. wide

and 5 ft. above high water. The original marsh surface was at about the high water level, and the material was mud for a depth of 15 ft., with coarse sand beneath.

A hydraulic dredge cut a channel 200 ft. wide and 35 ft. deep, and discharged the material in the fill in a direction parallel to the axis of the fill, and between longitudinal turf dikes. The waste water percolated through the turf, leaving the embankment firm enough to walk upon within a few hours. The turf of which dikes were formed was cut from adjacent salt marshes, and was laid up like masonry with a base as wide as the dike was high, and a top 2 ft. wide. The outside face was battered. The ordinary height was 6 ft. and above this the fill was retained by temporary wooden hurdles, made in sections 16 ft. long and 3 ft. high and by a horizontal platform 3 ft. wide built into the fill so as to give stability. The lumber used was matched 1-in. hemlock, nailed to 3 x 4-in. cross-pieces. The first cost of each 16-ft. hurdle was $4 to $5, and it cost 50 ct. each time one was shifted. Turf dikes 6 ft. high were constructed by 5 men at the rate of 20 lin. ft. in 10 hr., or nearly 3.6 cu. yd. of turf wall per man per day.

In forming the embankment, mud was deposited first and the sand on top. The fill was made 9 ft. high, but in a few days settled to a permanent height of 5 ft. above high water. The settlement of the embankment caused an upheaval of the mud on both sides.

The dredge had a 16-in. suction pipe, a 15-in. centrifugal pump with a diameter of 7 ft., and a 350-hp. engine. It had a rated capacity of 16,000 cu. yd. delivering a distance of 500 ft. in 32 working hr., or 500 cu. yd. per hr, when conditions were favorable. This dredge built 100 lin. ft. of fill in 10 hr., or 1,300 cu. yd. of 5 ft. fill. In one month a 90,000-cu. yd. fill was made, the dredge working 2 daily shifts of 12-hr. each. This was at the rate of about 1,700 cu. yd. per shift, or 150 cu. yd. per hr. When delivering material a distance of 1,100 ft. to an elevation of 20 ft. the discharge contained up to 30% of solid material.

Cost with Hydraulic Dredges on the Massena Canal. *Engineering News*, Oct. 30, 1902, gives the following data relative to the work of centrifugal pump dredges on the Massena Canal, from a paper read before the International Navigation Congress by John Bogart.

Dredge No. 1 was equipped with a 12-in. centrifugal pump, a rotary cutter, a compound condensing engine of 125 hp., and 12-in. suction and discharge pipe. This machine handled soft clay, loam and sand, but could not dredge indurated clay. The material was dredged at depths up to 22 ft., and discharged 30

ft. above the water level through 1,200 ft. of pipe. The discnarge averaged 25% solid material, the range being from 7 to 30%.

Dredge No. 2 was similar to No. 1 except that it was larger. It was equipped with 18-in. suction and discharge pipe. The material handled and the distance it was conveyed were exactly the same as for No. 1.

Each dredge worked two shifts of 11 hr. daily. Dredge No. 1 required the following crew per shift: 1 captain, 1 engineman, 1 oiler, 1 fireman, 1 deckhand foreman, 3 laborers at 15 ct. per hr. The total pay of 18 men for 11 hr. was $17.95. Dredge No. 2 required one more man (a spudman), and the total pay per shift was $20.95..

Dredge No. 1 worked 209 days each season. Careful observations for 194 days showed the average daily output to be 1,125 cu. yd. per day. Dredge No. 2 worked two seasons and removed 290,780 cu. yd., or an average of 1,544 cu. yd. per day. The daily (2 shifts) cost was as follows:

	12-in. dredge	18-in. dredge
Labor and supervision	$35.90	$ 41.90
Coal at $3 per ton	27.00	54.00
Oil, waste, etc.	5.00	8.00
Care during winter at $209	1.00	1.00
Interest, depreciation and repairs	26.80	40.19
Total per day	$95.70	$145.09
Cost per cu. yd., total, ct.	8.50	9.40

(Dredge No. 1 cost $40,000; dredge No. 2 cost $60,000. Interest at 4%; depreciation and repairs at 10%.)

Suction Dredge at Warroad River, Minn. At Lake of the Woods, Minn., a plant consisting of a suction dredge, wood barge, pipe line and floats, and small boats, total cost $29,130, was used to excavate a navigable tributary, the Warroad River. The work of this outfit is described by Emile Low in *Engineering News*, Nov. 29, 1906.

The dredge hull was 100 ft. long, 27 ft. wide and 8.5 ft. deep amidship. The total length, including the ladder and revolving cutter at the bow and the stern paddle-wheel, was 185 ft. The hull contained a sand bin amidship with a capacity of 100 cu. yd. The machinery included two 12-in. centrifugal pumps, one 16-hp. cutter engine, one 20-hp. hoist engine, two 10 x 60-in. stern wheel engines, one 6 x 10-in. duplex force pump, and four hand-power worm gears for operating the spuds. Steam was supplied by two 75-hp. marine boilers.

From May 7 to June 30, 1904, this dredge excavated a channel 1,380 ft. long, 100 ft. wide, and an average of 8 ft. deep, a total

of 8,625 cu. yd., at a total operating cost, including fuel, of 21.67 ct. per cu. yd. Storms caused a loss of 5.5 days. From July 1 to Oct. 29, 1904, a total of 26,923 cu. yd., or a daily average of only 259 cu. yd., were dredged. Storms caused a loss of 12.3 days. The material dredged was equal quantities of hardpan and mud with fibrous roots of bullrush, etc.

The total excavation for the twelve months preceding June 30, 1905, was 55,205 cu. yd. The cost, including fuel, was 13.03 ct. per cu. yd.

Dredging Silt with a Small Centrifugal Outfit. In order to remove the mud from the bottom of a Pittsburg reservoir, a dredging plant of simple construction was used. F. B. Marsh, in *Engineering Record*, Sept. 3, 1904, gives the following:

Two 50-hp. boilers, located on a dividing wall in the reservoir, and protected by board covering, supplied steam thro..gh a line of 4-in. pipe to the engine. The engine was of 75 hp., and was installed with an 8-in. Morris Centrifugal pump and the necessary suction pipes and other equipment, on a float, 20 x 30 ft. in size. The steam pipe was of wrought iron with a 40-ft. section having at each end a flexible ball-and-socket joint between two quarter-bends. This pipe, supported on the surface of the water by floats, permitted the dredge to swing freely. Rubber pipe connections were unsuccessful.

The suction pipe consisted of a 10-ft. length of rubber hose with a 22-ft. length of wrought iron 8-in. pipe to which the mouthpiece was attached. This mouthpiece was a 45° bend enlarging to 12-in., and turned down so as to rest on the mud. The discharge pipe from the pump to the embankment was 10-in., and the remaining pipe that carried the dredged material over the embankment was 8-in. Fully 10% of solid matter was carried. The lift was from 16 to 18 ft., the suction about 7 ft.

About 55,000 cu. yd. were dredged at an operating cost of about 10 ct. per cu. yd., or a total cost, including the cost of equipment, of 25 ct.

Cost at Wilmington, Cal. *Engineering News*, Aug. 16, 1906, gives the following: A hydraulic dredge was used in the harbor of Wilmington, Cal. The dredge was placed in commission Apr. 1, 1905, and from that time until June 30, 1905 (3 mos.) it dredged 227,464 cu. yd. of sand with shells and a small percentage of clay, cobbles, disintegrated sandstone and very compact and hard mud. The dredge was laid up 16 days during this period, leaving an actual working period of 2.5 months. The rate of dredging was therefore 91,000 cu. yd. per month.

The cost of the work during this period was as follows:

Routine office work, labor	$ 673
Care of plant and property, labor	180
Surveys, labor and supplies	156
Towing, dispatch work, labor, fuel, supplies	316
Alterations and repairs: supt., labor, fuel, water, lubricants, supplies	10,085
Deterioration of plant and property (estimated)	2,264
Total	$16,106

The original cost of this dredging plant was as follows:

20-in. suction dredge. "San Pedro" 600 hp. engines	$ 99,453
Gasoline launch, 30 ft. long, 16 hp. engine	1,733
Discharge pipe line	3,023
Rubber sleeves	1,275
24 pontoons; 1 water boat, 34 ft. long; 1 oil boat 34 ft. long; 1 derrick boat 29.5 x 11 ft.	6,501
Skiffs	154
Total cost of plant	$112,139

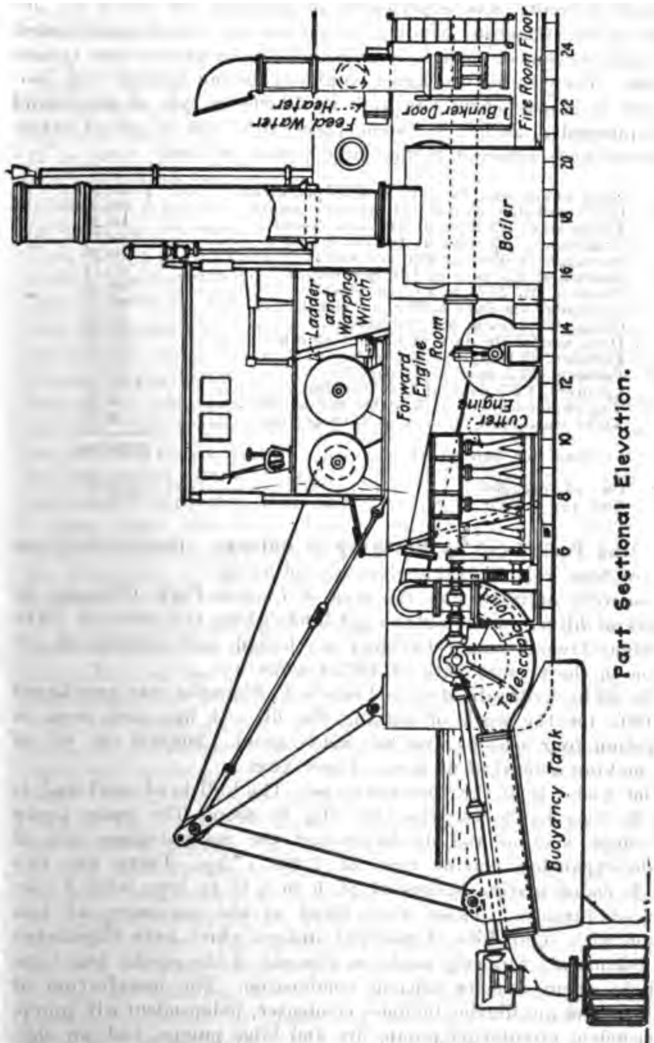
Hydraulic Dredging on N. Y. Barge Canal. The following data of the cost of certain work on contract No. 4 of the New York State Barge Canal, are given by Emile Low in *Engineering News*, Dec. 5, 1907: This work was performed by means of an hydraulic dredge. The depths of cutting ranged from 15 to 25 ft., the spoil banks being on the sides of the canal.

The dredge *Oneida* had a hull 97 x 17.5 x 10 ft. in size and a light draft of 5.5 ft. The suction pipes were two in number, and each was 19.25 in. diameter. The cutters were operated by two independent, compound, vertical, reversing engines of 21 hp. The main engines were of 750 hp. The pump was centrifugal in type with a runner 6.5 ft. in diameter. Steam was furnished by two boilers working at 200-lb. pressure. The discharge pipe was 26-in. The machine is illustrated in Fig. 14. The dredge as illustrated was not entirely stable and it was necessary to add a pontoon 6 ft. wide to each side.

In the beginning of Oct., 1906, one daily shift of 8 hr. was woked, and later two daily shifts of 8 hr. each were worked. In Nov., 1906, three shifts of 8 hr. each were worked. The working force per shift was as follows:

	Per month
1 operator	$100
1 engineman	100
1 engineman	80
3 firemen @ $70	210
1 spudman	60
1 oiler	50
4 ditch hands @ $50	200

In addition a gang was employed to shift the discharge pipe and repair the levees surrounding the spoil banks. There is also a night watchman and an engineman with a gasoline launch.



Part Sectional Elevation.

Fig. 14. Elevation of Front End of Dredge *Oneida*.

Much difficulty was experienced in building the levees on account of the numerous windings of the stream, which necessitated the construction of bridges over which the excavator was transported. The cost for the labor employed during October and November is given below. As high as 10,000 cu. yd. of quicksand were pumped in 24 hr., and some 12,000 to 17,000 cu. yd. of other material were removed in the same period of time.

Chief engineman, 55 days at $150 per month	$ 288.88
Chief operator, 55 days at $135 per month	260.00
Engineman, 129 days at $100 per month	445.93
Engineman, 129 days at $80 per month	356.74
Operators, 4 days at $130 per month	19.26
Operators, 125 days at $100 per month	431.11
Firemen, 387 days at $70 per month	936.44
Spudmen, 129 days at $60 per month	267.55
Oilers, 125 days at $50 per month	215.55
Deck hands, 516 days at $50 per month	891.84
Foremen, 58.4 days at $2 per day	116.75
Foremen, 84.3 days at $3 per day	102.75
Laborers, 1,277 days at $1.60 per day	2,043.20
Tug enginemen, 30 days at $80 per month	80.00
Night watchman, 30 days at $1.60 per day	48.00
Total for two months	$6,504.00
Cu. yd. dredged	183,055
Cost per cu. yd.	3.55 ct.

Filling Park Land by Dredging at Chicago. *Engineering and Contracting*, Feb. 22, 1911, gives the following:

The work of increasing the area of Lincoln Park, Chicago, by means of filling in the submerged lands along the shore of Lake Michigan from Diversey Parkway northward, and creating an addition to the present park of 197.54 acres.

The 30-in. hydraulic dredge *Francis T. Simmons* was purchased in 1907 for the work of making the fill. It has now been in operation four seasons and has made about 1,800,000 cu. yd. of fill, making a total of 68 acres of new land.

The dredge is of the open end type. The hull is of steel and is 148 ft. long by 38 ft. wide, by 10½ ft. deep. The main pump has 30-in. suction and discharge and the main engines are of triple expansion marine type of 1,200 i. hp. There are two double ended marine boilers 11 ft. 6 in. x 18 ft. long with 8 corrugated furnaces. These were fitted at the beginning of last season with eight Jones Underfeed stokers which have eliminated the complaints formerly made on account of the smoke and have brought about a more efficient combustion. The installation of engine room auxiliaries includes condenser, independent air pump, independent circulating pump, fire and bilge pumps, and an electric light outfit. The condenser is of sufficient size to receive the exhaust steam from the cutter engines as well as from the main

engines and all auxiliary engines. The rotary cutter is of a type adapted to hard and clay material capable of penetration with a pick, and can handle soft and sticky clay without clogging. The cutting edges are of hard steel and are removable. These will probably be changed before beginning next season's work as they have now worn down after two seasons' service. It is likely that manganese steel will be substituted. The dredge is anchored by heavy spuds operated by power. One of the spuds is used as a pivot about which the dredge makes a radial cut 175 ft. wide at one time. The maximum depth of the cut is 35 ft. The dredge is provided with a complete repair shop and with living quarters for the crew. See *Engineering and Contracting*, Dec. 5, 1907, for the design of the dredge. Considerable comment was made upon the use of a hydraulic dredge in Lake Michigan when this work was started, because it was predicted that it would be impossible to maintain a flexible discharge pipe line in the waves, and that more time would be lost on account of the weather than is the case with other types of dredges. As a matter of fact the proposition has been reversed and with the improved design of the discharge pipe, the dredge suffers less delay on account of weather than a barge loading dredge.

Pipe Line. The form of pipe line adopted (Fig. 15) is that of a central conduit, 30 in. in diameter carried by two cylindrical air chambers 33 in. in diameter, the three being rigidly held together by the frame. In this way no bolts or rivets are put into the air chambers and they may readily be taken apart. The sections are 95 ft. long, it having been found that shorter sections did not operate in a rough sea as well as the longer ones. The connections between the sections of discharge pipe are joined with the usual rubber sleeve, but the pontoons are connected with an arrangement which embodies the ball-and-socket principle, not in the pipe itself, but in a strong, steel frame above the pipe. This has proved entirely successful and the practical result is that the dredge is capable of continuing at work in all but the heaviest weather. The ball end of the joint is solidly bolted to the wood frames on the pipe, while the socket end is fitted to slide in a casing or frame and its movement is resisted by springs, as shown. These springs are heavy car springs, and are two in number. The springs are carried between spring plates in such a manner that they are compressed for either thrust or pull of the drawbar, the whole arrangement is built in the very strongest manner of steel, and each point is strong enough vertically to carry half the weight of an entire pontoon upon it. In other words, should the entire buoyancy be removed from one pontoon for 50 ft. of its length by the trough of a wave, its

weight would be supported upon the adjoining pontoon with safety.

In order to provide flexibility of the pipe at the point of leaving the dredge, a swivel elbow is employed and the first length of pipe is short and connected to the elbow by a pair of hinges. The axis of the hinges is horizontal while that of the swivel elbow is vertical; thus the movement of the pipe is universal. The pipe leaves the dredge at the corner in order to permit the pipe to radiate from the dredge at any angle through three-fourths of a circle. The horizontal hinges at the swivel elbow will permit the main pontoons to have a vertical or wave movement of 4 ft. The pipe is attached at one end, to the dredge, and at the land end to a terminal scow which is fitted with a steam winch, by which its own anchorage is controlled. This detail of passing the discharge line onto the land has been worked out in the practice of the last two years so that it is expected in the coming season to profit by the results. The method devised for future use is to anchor the terminal scow at the farthest point of fill, and, as the fill is made, to back the terminal scow away, thus eliminating the use of shore pipe entirely, the stopping of the dredge, and preventing a loss of time due to adding shore pipe. The length of the overhang of the discharge pipe beyond the terminal scow has been made 60 ft. in place of 30 ft. This change was made to prevent the scow from grounding on material flowing back under it from the discharge, a trouble which has previously caused some loss of time. Experiments were made of passing a pipe through the breakwater, as this was a more direct line from the dredge to the fill when the dredge was working in the open lake. At first the terminal scow was tied up to the breakwater and connected to the land pipe. This was found to be unsatisfactory because the scow was too easily affected by the wave action and was endangered by constantly bumping against the breakwater. A scheme was evolved by which the scow was done away with entirely, and the pontoons were connected directly to the pipe projecting through the breakwater from the land side. The first floating pontoon was guyed to the breakwater from the far end, enough slack in the cables being allowed to permit the pontoon to take a reasonable angle to its connection. The cables were fastened together at the middle with a special clip which could be loosed with one blow of a small bar so that a quick release could be obtained in case of necessity. At the time of exceedingly rough weather the dredge with its trailing pontoons could then be towed safely and easily into the harbor.

It is thus seen that the difficulties attending dredging work are

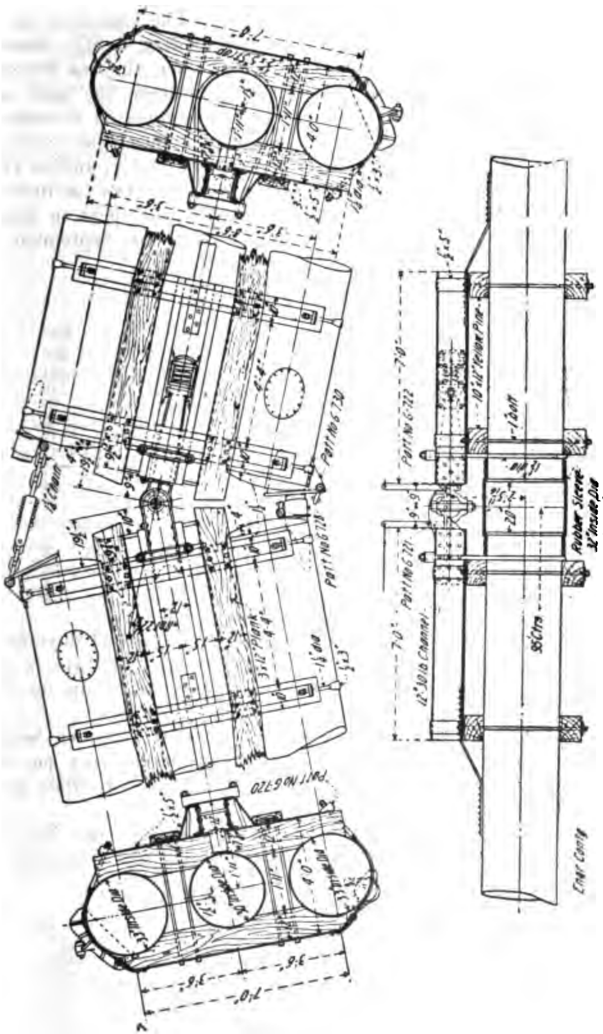


Fig. 15. Details of the Pontoon Discharge Pipe Connections Used in the Work in Lake Michigan.

much greater for work on the Great Lakes than for work on smaller lakes or upon other inland waters. The time lost on account of weather is less than by a scow loading dredge because such dredges are compelled to stop work when the sea becomes only so rough as to cause hard bumping between the scow and dredge. The time lost by the *Francis T. Simmons* on account of weather during the past dredging season of 7 mos., has averaged 18.2%. In 1909 the average was 9%, in 1908, 14.4%, and in 1907 it was 23.2%. During the 1910 season (Apr. to Oct. inclusive), there were 4,320 working hr., of which 60.2% was spent in pumping, and 39.8% lost. The following record for September is typical:

TIME LOST BY DELAYS

September, 1910	Hr.
Total available time	600
Dredge worked	381
Delays	219
Weather	57
Short pipe	32
Suction pipe, pumping and plug	11
Pontoon line	32
Swinging cables	15
Main engine	24
Spud engine	½
Cutter engine	..
Cutter shaft	..
Moving dredge to new cut	5
Towing and preparation	34
Miscellaneous	1
Stones	7

During the month of September the dredge worked 11 days from a position outside the breakwater protection and 11 days in the yacht harbor. The balance of the time was taken up by bad weather, Sundays and holidays.

The cost of the work for the season of 1910 is shown below. The items of tug service are calculated at actual cost per hr. of service. The cost of operation of the tugs and other auxiliary machinery is given later.

During the season of 1910, the total yardage was 570,243, the dredge being in commission 4,320 hr., and the cost was as follows:

Operation:	Per cu. yd.
Labor	$0.0243
Fuel	.0300
Supplies, tools, sleeves, ——, etc.	.0076
Commissary labor and supplies	.0104
Field repairs, labor and material	.0106
Tug service	.0238
Derrick service	.0005
Motor boat	.0010
Insurance	.0060

Winter repairs and fitting up:

Labor	.0093
Material	.0037
Fuel commissary and tools	.0018
Tug service	.0013

Totals

Operation	.1142
Repairs	.0161
Operation and repairs	$0.1303

The repairs shown with the operating expenses include the minor repairs made during operation, which those shown under the head of winter repairs are for repairs made during the winter season in preparation for the work of the summer of 1910. Some of the field repairs included the relining of several pontoon discharge pipes. This work costs about $225 per pontoon, $125 for material and $100 for labor. The pipe is relined with a strip of ⅜-in. sheet steel, 36 in. in width, placed in the bottom of the pontoon to fit the circumference. The pontoons are 95 ft. long. When relined they are expected to last three of four seasons. The winter repairs consisted of overhauling the engines, boilers, furnaces, stokers, and replacing steam pipe connections. The engines were relined, the shafts rebabitted and rebushed. The heaviest wear, however, is on the cutter mechanism. The cutter ran two years without renewal of blades. The next blades put in, however, will probably be of manganese steel and are expected to last longer. The centrifugal pump runner lasts about two seasons and costs $600. It is of cast steel with a steel lining on the blades. The other repairs consist of cleaning and scraping the steel hull and painting.

Table I is a summary of the costs and performance of the dredge for the past four seasons, or since the dredge was built. It must be noted here that the yardage as given for the years 1907–8 and 9 was calculated from the cut, while that for 1910 has been calculated from the total amount in place. For this reason the season of 1910, which is believed to have been the best season's work yet done, does not show well in the comparison.

The operating crew of the dredge is as follows:

	Per month
1 chief operator	$150.00
1 assistant operator	125.00
1 chief engineman	150.00
1 assistant chief engineman	110.00
4 oilers	66.00
4 firemen	66.00
4 coal passers	55.00
2 spudmen	66.00
1 janitor	55.00
8 deckhands	55.00

TABLE I. FOUR YEARS' OPERATION OF DREDGE

Cubic yards	457,242*	672.815*	518,920*	570,243†
Cost	$54,241.19*	$88,459.17*	$69,202.32*	$74,440.49†
Cost per cu. yd.	$0.118	$0.131	$0.133	$0.130
Hours in commission	2,940	27.6	3,291	4,320
Hours pumping	1,088 = 37 %	4,500 = 60.6%	2,117 = 64.3%	2,599
Hours delayed account weather	683 = 23.2%	636 = 14.4%	294 = 9.0	788 = 18 %
Hours delayed miscellaneous	1,169 = 39.8%	1,100 = 25 %	880 = 26.7%	933 = 21.6%
Hours delayed total	1,852 = 63 %	1,736 = 39.4%	1,174 = 35.7%	1,720 = 39.8%
Output per pumping hour, cu. yd.	426	245.8	245	220
Cost of coal	$10,131.04	$16,050.68	$11,584.37	$17,000.35
Cost of coal per cu. yd.	$0.022	$0.024	$0.022	$0.03

* Based on calculation of cut measurement.
† Based on calculation of place measurement.

Commissary:

1 steward	86.00
1 second cook	40.00
1 porter	40.00

The men receive their board in addition to the wages listed. They work two 12-hr. shifts. For overtime they are paid time-and-a-half and if worked Sundays (which is extremely seldom), they get double time. All overtime is paid for in addition to and not considering their regular wage. This is in accordance with the union rules on the great lakes.

The dredge is working in very stiff gumbo clay which is covered with a layer of from 3 to 5 ft. of sand. The depth of the dredging at Chicago is from 18 to 35 ft. and the material was deposited through about 2,000 ft. of pipe.

Cost of Dredge. The following table gives the list of items which together make up the cost of the dredge as it was put in operation in 1910:

Engineering, plans, inspection, etc.	$ 9,816.45
Contract (1907) with 2,000 ft. pontoons	151,402.19
Terminal pontoon scow (1907)	1,227.88
8 Jones underfeed stokers (1908)	6,700.00
6 pontoons (1908)	10,485.00
Miscellaneous	874.04
Total	$180,505.56

Cost of Tenders. In connection with the dredging work and other construction tributary to the Park Extension work, a fleet of tugs, derricks and other floating apparatus was employed. The cost of operation of each of these for the past year is given below, together with the original cost, maintenance cost, and a brief description of the apparatus.

The tug *Keystone* has a steel hull, 87½ ft. long, 19 ft. beam, and 11 ft. deep. She is of 94 gross ton weight, and was built in 1891. She contains 1 fore and aft compound condensing engine with 18 x 34-in. cylinders of 30 in. stroke, and one fire box marine boiler 14 ft. long by 102 in. in diameter carrying steam at 125 lb. The crew is as follows:

	Per month
1 captain	$165.00
1 engineman	120.00
2 firemen at	65.00
1 deckhand	65.00
1 scowman	65.00
1 watchman	66.00
1 cook including supplies	225.50

This tug was in commission 12 hr. per day. Board was furnished the men in addition to the regular wages. The tug was purchased by the Park Commission in 1905 at a cost of $13,983.19,

including improvements, and was fitted with Jones underfeed stokers in 1910 at a cost of $2,025, making its total cost $16,-008.19. It has been in commission 2,348 hr. The cost of operation has been as follows:

	Cost	Cost per hr.
Labor operation	$5,485.63	$2.336
840 tons coal	2,772.50	1.180
Supplies	915.56	.390
Insurance	127.50	.055
Labor repairs	1,057.76	.450
Material repairs	903.06	.385
Total cost of operation	$9,301.19	$3,961

Summarizing we get the following costs:

Total cost of repairs	$1,960.82
Cost of operation per hr.	3.961
Cost of operation per day	47.55
Cost of repairs per hr.	.835
Cost of repairs per day	10.05
Cost of operation and repairs per hr.	4.80
Cost of operation and repairs per day	57.60

This tug was used mostly for towing scows loaded with loam for park purposes, but 89 hr. of its time have been charged to the dredging.

The tug *Richard B*, another member of the fleet, is 76 ft. long, 17 ft. beam, and 7 ft. in depth. She has a wood hull and is rated at 63 gross tons. She is equipped with one fore and aft compound condensing engine 10 x 20-in. cylinder with 14-in. stroke. Her boiler is Scotch Marine type, 14 ft. long by 96 in. in diameter, and carries 125 lb. of steam. She was built in 1906. Her crew consists of a captain at $145, an engineman at $120, a fireman and a lineman each at $65. The tug was purchased by the Park Commission in 1905 for $8,744.55, which price included some repairs and improvements made on it, before placing it in commission. The cost of operation and repairs during the season of 1910 were as follows:

Hours in commission	1,118
Hours leased	732
Hours on park extension	386

	Cost
Labor operation, 386 hr.	$ 476.88
Fuel, 386 hr.	315.75
Supplies	104.03
Insurance	95.00
Labor repairs (winter)	511.35
Material repairs	534.41
Towing repairs	21.76
Total operation, 386 hr.	991.66
Total repairs, 1,118 hr.	1,067.52

Total operation and repairs	2,059.18
Total cost per hr.	3.53
Total cost per day	42.36

The time of this tug was charged to the dredge work for 139 hr. It was in commission 12 hr. a day.

The tug *Hausler*, the last of the three tugs belonging to the fleet, is 72 ft. long, 18 ft. beam, 9 ft. deep, and is rated at 61 gross tons. She was built in 1893 of wood. Her machinery consists of 1 vertical non-condensing engine, 22 x 44-in. cylinder with 24-in. stroke. She has 1 fire box marine boiler, 14 ft. long x 96 in. in diameter, carrying 135 lb. of steam. Her crew, a double crew, during the past season each consisted of a captain at $165, an engineman at $120, and two firemen and one deckhand at $65. She was in commission 24 hr. per day. This tug was purchased in 1908 for $10,500. The cost of operation and repairs for the season of 1910 is as follows, for 5,537.5 hr. in commission:

	Total	Cost per hr.
Labor operation	$ 8,283.92	$1.496
Fuel, 773 tons	2,903.00	.524
Supplies	369.65	.667
Insurance	250.00	.045
Labor repairs	1,317.26	.238
Material repairs	1,897.63	.343
Towing repairs	14.12	...
Total operation	11,806.57	2.13
Total repairs	3,224.01	.59
Total cost	15,035.58	2.72

This tug devoted nearly all its time to the dredge.

The motor boat which was used for transportation of the men and for other purposes was purchased in 1907 for $1,150 and operated for 7½ months during the season of 1910. Its cost for the season, time in commission 7½ months, was as follows:

Labor operation	$449.14
Labor repairs	62.80
Supplies	264.36
Derrick, 2 hours at $1.60	3.20
Total cost	$779.50
Cost per month	103.92
Cost per day	4.00

About 146 days of the motor boat's time was charged to the dredge.

The floating derrick, which was employed for various duties on all the work, was purchased in 1905 at a cost of $5,287.26. Its cost of operation for the past season is as follows:

Hours in commission	1,783.5
Labor operation	$1,871.29
Fuel and supplies	599.07
Insurance	100.00
Labor repairs	268.70
Towing	17.62
Total	$2,856.68
Total cost of repairs	286.32
Total cost of operation	2,570.36
Total cost per hr.	1.60
Total cost per day	16.00

The derrick was in commission 10 hr. per day and was operated by a crew consisting of an engineer and fireman with a varying number of deckhands — usually about four.

Engineering and Contracting, Apr. 9, 1913, gives the following additional data:

A total of 3,662,525 cu. yd. of hydraulic dredge fill has been completed in the work of reclaiming for Lincoln Park, Chicago, an area of 200 acres from Lake Michigan. The average cost of this fill has been 14½ ct. per cu. yd. Altogether 139.06 acres have been reclaimed.

The dredging was done by the 30-in. hydraulic pipe line dredge built in 1907 and in commission from April 8 to Nov. 16, 1912, a period of 4,524 hr., of which 2,954 hr., or 65% of the time, was employed in pumping. The weather throughout the season was very unfavorable for dredge operation outside of the breakwater and work was confined within the yacht harbor about half the season. The yardage dredged in 1912 was 899,701 cu. yd. The time report of the dredge may be summarized as follows:

Total working hours		4,524
Hours delay:		
Weather, 10%	451	
Other causes, 25%	1,119	
Total delays, 135%		1,570
Time pumping		2,954

The cost of operating the dredge is given below. In this table the items "repairs" include only those repairs made during the operating season. The cost of the more extensive overhauling repairs made during the season during which the dredge was out of commission are shown.

The items for tug service, derrick, motor boat scows, etc., are prorated from the accounts showing the cost of operating these pieces of plant. The cost of operating a derrick, or a tug, for example, is kept account of throughout the season and the cost per hr. is obtained. Its time is then distributed to the various jobs

upon which it has served and charged against each job at its calculated cost per hr. The cost of operation for 899,700 cu. yd. was as follows:

Labor operating	$16,506
Commissary:	
Labor	1,500
Supplies	5,560
Total	$ 7,065
Repairs:	
Labor	$ 3,873
Materials	8,444
Total	$12,317
Attendance:	
Tug service	$18,804
Motor boat	853
Scows	410
Teams	40
Derrick	1,703
Total	$21,810
Fuel	17,901
Dredge supplies	4,783
Administration	2,473
Insurance	4,250
Grand total at 9.7 ct.	$87,105

COST OF OVERHAULING REPAIRS DURING WINTER

Item	
Labor	$ 8,667
Fuel	1,195
Materials	4,587
Dredge supplies	443
Commissary supplies	564
Service, tugs, derrick, teams	782
Total repairs	$16,238
Repairs per cu. yd. excavation	1.8 ct.

The ground on which the Panama Pacific International Exposition was built was submerged in many places, the average high tide-level being about elevation —5.5. ft. and the average elevation of the non-submerged section of the height was about + 1.5 ft. About 1,300,000 cu. yd. of fill were pumped into the submerged area, bringing the surface to elevation —2.75. The material in the fill averaged from 16 to 17% sand, the remainder being mud and silt. Due to the superior weight and density of this material it crushed its way 2 to 5 ft. into the soft sand and ooze of the old bottom to such an extent that where the original sounding showed elevation —15 the actual bottom of the fill was nearer elevation —20.

Breaking Up Clay for Dredging. This is described in *Engineering and Contracting*, Feb. 12, 1908. The foundation walls for a bridge were sunk through sand and clay, the latter being dark blue and very hard. It was brittle when quite dry, but like leather when under water. A dredge was used to remove the overlying sand but could make no impression on the clay. Accordingly the following method of breaking up the clay was employed: Five double-headed rails each 20 ft. long, and weighing 60 lb. per yd., were riveted together. Two outer rails were splayed outward like a trident and were sharpened. The center rail was also sharpened, and the two others were cut off at about 2½ ft. from the end. This arrangement was worked up and down

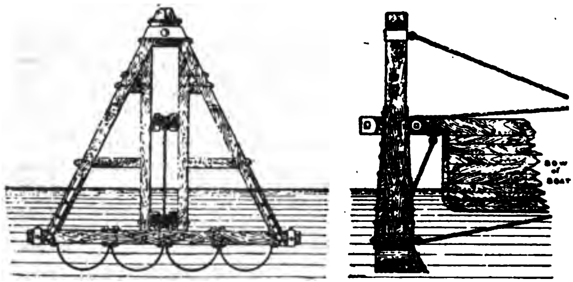


Fig. 16. Scraper for Lowering Sand Bars.

by a steam hoist, and, being top heavy, when it was driven into the clay it tended to fall over, thus breaking up the clay. In this manner a hole 1 ft. deep and 13½ ft. in diameter could be dug and dredged in 24 hr.

Scraper for Lowering the Crest of Sandbars. For temporarily increasing the depth on a sandbar in the Mississippi River, scrapers were used, Fig. 16. This device was invented by Col. Stephen H. Long, Corps of Engineers, U. S. Army. It consisted of a triangular frame of oak timber, with buckets or cutters of boiler iron bolted to the lower side. It was attached by bolts to the sides of a boat and was raised or lowered by two ropes, one of which was fastened to the bow of the boat and passed under a pulley near the lower end of the frame; thence over a pulley on a bow sprit projecting from the boat, and thence to the forward steam capstan. The other rope was attached to the apex of the triangular frame, passed over a pulley connected to the shear boom and thence to an aft capstan. The method of operating this scraper was to move the boat to the head of the shoal to be

dredged, and lower the scraper on the bar. The steamer was then backed so as to drag the scraper over the bar, the floats floating with the stern down stream. After having been dragged across the bar, the scraper was raised out of the water and the steamer returned to the initial point. The operation was then repeated until the desired depth was obtained. The buckets cut up and loosened the material on the bar and then conveyed it down stream and deposited it in deep water, being assisted in the movement of the material by the river current. These scrapers are effective for temporarily increasing the depth on a bar; but for work of permanent character, the ordinary dipper dredge is more economical.

Sweeping and Cleaning Up a Dredged Channel. A combined diving, sweeping and derrick scow, used in cleaning up a dredged channel in the Delaware and Schuylkill River channel improvement at Philadelphia, is described in *Engineering and Contracting*, Apr. 10, 1907. A small dump scow, carrying a hoisting engine and derrick, was used for the work. The middle pocket of the scow was floored over a few feet above the water line and housed in. Two small winding drums, fitted with cranks, ratchets and pawls, were placed at the two corners of the stern or hoisting end of the scow. Upon each drum was wound about 40 ft. of light steel wire hawser, the ends of which were connected to a steel sweeping bar, 1 in. by 6 in. by 30 ft. in length. Both hawsers were graduated at the required lengths from the cross or sweeping bar in alternate black and white foot marks corresponding to the marks on the dredging tide gage. Bow, stern, starboard breast and port breast anchors held the scow in position, the scow being moved over the shoal places by the action of the current, the rate and direction of motion being controlled by the anchor lines. In operation, the scow was brought to the desired position by the anchor lines, and the sweeping bar lowered to the desired depth as indicated by the height of water on the tide gage. The diver then descended and grasping the sweeping bar, walked along the bottom with the current. When the bar struck an obstruction above the grade line, the watchmen in charge of the winding drums were aware of the fact, as well as the diver. The movement of the scow was stopped instantly and the diver removed the obstruction, tools being lowered to him if necessary. He then placed a chain around it and attached it to the derrick hoist, by means of which it was lifted to the deck. The work was done in an entirely satisfactory manner, at a cost said to be not more than one-half of that of operating a dredge in an effort to perform like work. Two divers were employed, working 6-hr. shifts.

Cost, Life and Repairs of Barges, Tow-Boats, and Dredges.

The following is taken from *Engineering and Contracting*, July 17, 1912, being an abstract of an article by Mr. C. W. Durham in *Professional Memoirs:*

During a period of 30 years (1881–1911) the upper Mississippi improvement has owned and employed 282 barges (scow), 12 barges (model), 90 quarter-boats, office-boats and store-boats, 3 steam drill-boats, 4 dipper dredges, 5 hydraulic dredges, 7 pile drivers, 23 dump boats, 3 snag-boats, 16 tow-boats of various sizes, and a very large number of small steam and gasoline launches, motor and ordinary skiffs, pontoons, and other small pieces.

Scow Barges. 100 x 20 x 4½ ft. is the standard size of all 100-ft. barges hereafter mentioned. This district also uses a standard barge, 110 x 24 x 5 ft., of practically the same construction as the 100-ft. barge, and for the purposes of this article the same design applies to all barges and to quarter-boat and drill-boat hulls, except the model barges and those bottom planked fore and after.

The barges used in the earliest years of this improvement for carrying rock and brush, were mostly of smaller size (80 x 16 x 4 ft.) than those at present employed, where built of white pine, and with calking and nominal repairs, gave good service for periods ranging from 8 to 11 years. The first cost of these averaged $675 in 1882.

Early in the improvement six oak model barges, 135 x 26 x 5½ ft., were built on the Ohio River, three by Howard, of Jeffersonville, Ind., and three by Cutting, of Metropolis, Ill. These barges, numbered 60–62 and 88–90, were built in 1882 at $3,500 each, and were not condemned until 1901, but for five or six years previous the repairs were very heavy. These barges were in use 18 years.

Sixteen barges (100 x 20 x 4 ft.) of white pine cost $770 each in 1891, and had a life of 7 years, during which the repairs averaged $42 a year per barge.

Nine barges (100 x 20 x 4 ft.) of Douglas fir cost $800 each in 1892, and had a life of 15 years, during which the repairs averaged $70 a year.

Six white pine barges (120 x 20 x 5) cost $1,300 each, in 1891, and had a life of 21 years during which they rebuilt once; but the entire repairs and rebuilding averaged only $12 each per year.

Dump Scows. Twelve dump scows (78 x 18 ft.) of 8 side pockets; each cost $1,650, built from 1885 to 1896. Their useful life averaged 8 years, whether of oak or fir. The annual repairs averaged $140 a year, or nearly 9%.

Tow Boats. Two large tow boats built in 1881, cost $12,000 each. Their hulls were 100 x 19 ft., boiler 22 ft. x 42 in. After 30 years' service they were "fair" (needing extensive repairs). The two hulls were replaced in 1895 and 1899, the repairs for each boat being about $5,000 for each of those years. Inclusive of these new hulls, and new boilers in 1895 for one of the boats ($3,000), the average annual repairs over the period of 30 years were $1,000 per boat per year, or about 8% of the first cost.

Two small tug boats were built in 1885, at a cost of about $3,800 each. At the end of 25 years the annual repairs on each had averaged $460, inclusive of hull renewals.

Two small tug boats were built in 1889 at a cost of $4,000 each; the hull being oak, 67 x 12 x 3 ft., boiler 10 ft. x 34 in., cylinders 6 x 28 in. After 21 years they were in good condition, the repairs during that period having averaged $450 each per year, including three hull renewals, or 1½ hulls per boat in 21 years. A similar tug boat with a steel hull cost $5,100 in 1889, and its repairs averaged $360 a year for 25 years, or 7% annually.

Dredges. The "Ajax" is a dipper dredge built in 1876, oak hull (80 x 30 x 8 ft.), at a cost of $11,309. The hull was renewed in 1894. At the end of 1910 it was in good condition, the repairs and renewals having averaged $1,030 a year for 34 years, or 9% yearly.

The Vulcan dipper dredge, built 1883, cost $19,450, and its annual repairs up to end of 1910 had averaged $1,350, including hull renewals. It has oak hull, 80 x 30 x 8 ft.; nominal repairs to 1890; hull rebuilt in 1892–1893 and 1908–1909; condition now good, although annual repairs have been large for the past eight years.

The Phoenix, built 1885, oak hull, 80 x 8 ft.; nominal repairs to 1890, hull rebuilt in 1895–1896; burned and entirely rebuilt using a portion of the old machinery in 1908–1909, at a cost of $19,581, now in good condition. First cost was $19,525, and the annual cost of repairs and renewals has averaged $1,600.

The Hecla, 15-in. suction dredge, with eleven pontoons, built by United States in 1901; hull, fir and oak, 120 x 26 x 5 ft.; rebuilt 1909–1910; good condition. Its first cost was $27,700, and the repairs have averaged $2,300 a year for 9 years, or about 8.3%.

The cost of repairs and renewals by years will be found in the article from which the foregoing is abstracted.

Cost of Repairing Barges. *Engineering and Contracting*, Apr. 24, 1912, gives the following: A comparison of costs of repairs

to barges constructed of treated and untreated timber is made in a paper presented to the American Wood Preservers' Association, by A. E. Hageboeck, United States Inspector at Rock Island, Ill. Some 200 barges are now maintained for river improvement work in the Rock Island District, and records of the maintenance costs of these barges, which are all of a standard size (100 x 20 x 4 ft. 7 in.), are had for the last 20 years. The comparative costs given by Mr. Hageboeck are, therefore, based on unusually comprehensive records.

In constructing light draft barges it has been the policy to use pressure creosoted fir, as fir can be obtained in long lengths at a reasonable cost. Long timbers are especially desirable in

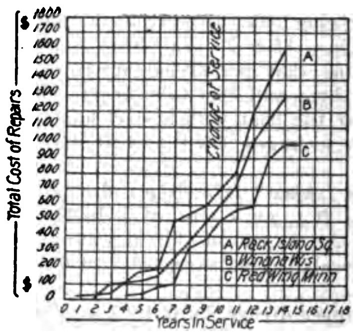


Fig. 17. Average Cost of Repairs and Life for Untreated Douglas Fir Barges.

barge construction, as they reduce to a minimum the number of gunwale joints which are always the first to cause trouble by leaking. Besides being cheaper in cost, both before and after creosoting, the fir is lighter, resulting in a draft of but 9 in. for a standard barge 100 x 20 x 4 ft. 7 in.

Kinds of Treatment Used in Barge Construction. The first creosoted barges used in this country were built in 1900 of pressure treated yellow pine by the New Orleans office of the U. S. Engineer Corps. These barges are today in a perfect state of preservation, and in all probability will be used for 10 to 12 years longer. The cost of repairs has been light, and the results so satisfactory that no untreated barges are now built by that office.

The Rock Island District formerly used the open-tank treatment. The penetration was usually superficial, but the cost is

only 5% of the total cost of a fir barge. Last fall the writer inspected a large number of these fir barges built in 1908, and in no case was any evidence of decay found on the treated timbers, while in a number of cases the untreated timbers had reached an advanced stage of decay. It is, therefore, evident that the small cost of this treatment will pay good returns on the money invested. In the case of 90% heart Long Leaf Pine, the same conditions exist, as the penetration on the heart surfaces is usually superficial. With Short Leaf and Lobolly pine it has been our experience that so much oil is required to saturate the sap that it often costs more than a 10-lb. pressure treatment. For treating barge timbers the pressure treatment has a number of advantages that make it a far more economical treatment. First, from a treating standpoint, it is possible to treat either green or seasoned lumber. Second, the exact quantity of oil injected can be ascertained by the temperature and gage readings. Third, the entire treatment can be regulated to meet the requirements of each particular charge. Fourth, it is possible to plug the ends of the timbers and thereby retard the absorption of moisture. Fifth, the penetration of oil is far more uniform. The last two factors tend to eliminate the so-called "working" of the timbers. This is an important item in barge construction, as it is a well-known fact that a barge built of green, untreated lumber will usually cause trouble from leaking, due to the subsequent shrinkage of the timber as it dries, and the consequent opening of the seams and loosening of the oakum. Even after the lumber has once become dry it readily absorbs moisture during a wet period, and again gives it up during a dry period, and as a result an untreated barge is re-calked every year after its fourth or fifth year in service. The pressure treatment has largely eliminated this re-calking and so materially reduced the cost of repairs.

Life of Untreated Yellow Pine Barges. On the Mississippi River, between St. Paul and St. Louis, untreated yellow pine has been used but little, and the writer has been unable to obtain any accurate records of its lasting qualities. It is generally believed that unless timber, practically free from sap is obtained, its life would be exceedingly short. On the Lower Mississippi River a yellow pine untreated barge containing a minimum proportion of sappy timber is past economical repairs at the end of 10 years.

Life of Pressure-Treated Yellow Pine Barges. Pressure-treated yellow pine barges have been used on the lower river for 12 years. These barges are today in a perfect state of preservation, and without doubt are good for an additional life of 10 years. It

has been found necessary to re-calk the barges after two years' service, but otherwise the repairs have been small, and but little further re-calking seems necessary during the life of the barge. One reason given for this re-calking is that the creosote oil acts on the oakum and "burns" it out. As a matter of fact, however, the lumber in these barges was treated while in a green condition, and, the real necessity for re-calking is due to the subsequent shrinkage of the timber and consequent opening of the seams and loosening of the oakum.

On the Lower Mississippi River, where there is always a good stage of water, light draft is not a controlling factor, and so barges 120 x 30 x 6 ft. are in general use. The original cost of these untreated yellow pine barges, built in the early 90's, was about $3,000; the cost of repairs during the life of 10 years averaged $2,006 per barge.

The original cost of similar barges built of pressure creosoted yellow pine was $4,000; the annual cost of repairs on 10 barges averaged $557 each. The life of the untreated barge is 10 years, as against 22 years for the treated barge.

Life of Untreated Douglas Fir Barge and Cost of Repairs. With few exceptions the necessity for repairs to an untreated barge are due to decay and not to mechanical abrasions. Ordinarily the decks of barges used for rock transportation will first decay on the bottom side at the points of crossing other timbers, and in this weakened condition are easily broken.

It has been necessary to replace plank originally 2½ in. thick, which after eight years of service were 2⅜ in. thick, because of their decayed condition, and not because of wear. It is not uncommon to find evidence of decay on untreated barges after three years of service.

The repair costs used in Fig. 17 have been obtained from the plant records of the U. S. Engineer office at Rock Island, Ill., covering Douglas fir barges in use for the past twenty years in connection with the work of improving the Upper Mississippi River, between St. Paul and St. Louis. In the past untreated fir barges were kept in service 10 to 17 years, the average life being 15 years. The diagram is intended to show the usual cost of repairs from year to year during the life of an untreated Douglas fir barge. New barges are, as a rule, used for rip-rap rock transportation, this service requiring a substantial craft. From the diagram it will be noted that during the sixth and seventh years the barges required extensive repairs, the cost ranging from $200 to $300 per barge; that with repairs costing about $75 per year they continued in hard service to the tenth or twelfth year; that they then required large repairs and had

to be taken from rock work and placed in the brush carrying service, which is much less severe on account of the large decrease in weight per cu. ft. of load. From this time on to the end the cost of repairs per barge is largely increased; and it is debatable whether it would not be fully as economical to abandon the barge at about the tenth or twelfth year.

Life of Pressure-Treated Douglas Fir Barges and Cost of Repairs. It seems safe to estimate the life of creosoted fir barges at 20 years, since untreated barges have given an average life of 15 years. The major portion of the repairs on an untreated barge are for calking and repairs to deck, rake and gunwale joints on account of decay. As the present tendency is to air season the fir before treatment, it seems natural to believe that the barges will give a long service without recalking, as was the case of the creosoted barges used on the lower river, as cited above. As an additional precaution it is thought advisable to protect the creosoted deck with a 1-in. wearing surface of untreated material. The repairs to the deck are, therefore, confined to the occasional relaying of this protection.

The average cost of repairs on 31 fir barges (100 x 20 x 4.5 ft.) used on the Upper Mississippi River was $73 per year per barge during an average life of 15 years. The original cost of such an untreated barge built today would be approximately $1,200. On this basis, with interest at 5%, the cost per untreated fir barge per year would be $236, as compared with $177 yearly cost for a creosoted fir barge, or a difference of $59 per year in favor of the creosoted barge. The first cost of a treated barge of this size, is $1,500, and its annual repairs $20. The first cost of a steel barge of this size is $4,000, and its life may be estimated at 25 years.

The figure for interest on repairs was obtained in this way: First, the average cost per year for repairs on 31 average untreated barges was obtained, and the interest figured from the time the repairs were made until the barge was condemned. The figure for interest on repairs of the creosoted barges was obtained by proportion.

Cost of Year's Operation of Marine Plant for Construction of Lincoln Park Extension, Chicago, Ill. The cost of operation and repairs during the year 1912 for three tug boats, a pile driver, a derrick and a motor boat is given in the accompanying table which are taken from *Engineering and Contracting*, March 26, 1913. This plant was used in connection with the dredging and breakwater construction for the extension of Lincoln Park, Chicago.

The tug *Keystone* is the largest of the three tugs and is rated

at 94 gross tons. She was built in 1891 and has a steel hull, 87½ ft. long, 19-ft. beam, and 11 ft. deep. She is equipped with one fore and aft compound condensing engine with 18 x 34-in. cylinders of 30-in. stroke, and one fire box marine boiler 30 ft. long by 102 in. in diameter.

TABLE I. OPERATION AND REPAIRS — TUG "KEYSTONE"
In commission 2,125 hours

	Totals
Operation:	
Labor	$ 5,284.74
Fuel	3,469.15
Supplies	1,105.12
Insurance	147.00
Miscellaneous	1.93
Total	$10,007.94
Repairs:	
Labor	$ 2,975.45
Material	4,239.04
Service of other plant	485.63
Total repairs	$ 7,700.12
Total operation and repairs	17,708.06
Total cost per hr.	8.33

The tug *Richard B* was built in 1906. She has a wood hull 76 ft. long, 17-ft. beam and 7 ft. in depth, and is rated at 63 gross tons. Her engine is fore and aft compound condensing, with 10 x 20-in. cylinder, and 14-in. stroke. Her boiler is of the Scotch Marine type, 14 ft. long by 96 in. in diameter.

TABLE II. OPERATION AND REPAIRS — TUG "RICHARD B"
In commission, 2,963 hours

	Totals
Operation:	
Labor	$ 4,619.47
Fuel	1,467.45
Supplies	713.06
Insurance	114.50
Total operation	$ 6,914.48
Repairs:	
Labor	$ 1,061.00
Material	1,493.37
Service of other plant	47.95
Total repairs	$ 2,602.32
Total operation and repairs	9,516.80
Total cost per hr.	3.22

The tug *Hausler* was built in 1893 of wood and was purchased for its present work in 1908 for $10,500. She is rated at 61 gross tons and is equipped with one vertical non-condensing en-

gine, 22 x 44 in., 24-in. stroke. She has one fire box marine boiler, 14 ft. long by 96-in. diameter, and carries 135 lb. of steam. The other tugs each carry 125 lb. of steam.

TABLE III. OPERATION AND REPAIRS — TUG "HAUSLER"

In commission 5,730 hours

	Totals
Operation:	
Labor	$ 9,532.94
Fuel	3,464.30
Supplies	1,112.14
Insurance	288.25
Total	$14,397.63
Repairs:	
Labor	$ 1,628.05
Material	1,692.74
Service of other plant	151.57
Totals	$ 3,472.36
Total operation and repairs	17,869.99
Total cost per hr.	3.12

Pile driver No. 1 is a floating driver which was used for constructing breakwater. This piece of plant was in commission 878 hr. and Table IV shows the expense incurred.

TABLE IV. OPERATION AND REPAIRS — PILE DRIVER NO. 1

In commission 848 hours

	Totals
Operation:	
Labor	$ 4,601.92
Fuel	176.59
Supplies	217.37
Insurance	97.00
Total	$ 5,092.88
Repairs:	
Labor	$ 1,255.20
Material	239.72
Service of other plant	76.32
Total repairs	$ 1,571.24
Total operation and repairs	$ 6,664.12
Total cost per hr.	7.59

TABLE V. OPERATION AND REPAIRS — PILE DRIVER NO. 2

In commission 717 hours

	Totals
Operation:	
Labor	$ 3,809.62
Fuel	127.30
Supplies	163.08
Insurance	97.00
Total operation	$ 4,197.00

Repairs:	
Labor	$ 1,121.55
Material	183.94
Service of other plant	107.83
Total repairs	$ 1,413.32
Total operation and repairs	$ 5,610.32
Total cost per hr.	7.82

The cost of the season's work of Pile Driver No. 2 is shown in Table V.

The derrick was in commission 1,910 hr. and served to handle stone from barges, and for handling materials on all parts of the work. The cost for the season is shown in Table VI.

TABLE VI. OPERATION AND REPAIRS TO DERRICK

In commission 691 hours crew of 2 men
In commission 200 hours crew of 4 men
In commission 1,019 hours crew of 6 men

Operation:	Total
Labor, watching	$ 321.67
Fuel	288.06
Supplies	226.31
Insurance	22.00
Total	$ 798.04
Repairs:	
Labor	$ 345.60
Material	236.93
Total	$ 582.53
Total operation and repairs:	
Except operating labor	$1,380.57
Total with 2 men 691 hr.	771.13
Total with 4 men 200 hr.	502.70
Total with 6 men 1,019 hr.	3,391.87

The motor boat which served all the work was in commission eight months. This boat was purchased by the Park Commission in 1907 for $1,150. Its cost for the season is shown in Table VII.

TABLE VII. COST OF OPERATING MOTOR BOAT

Operation:	Totals
Labor operating	$ 496.10
Labor watching	80.42
Supplies	546.91
Total	$1,123.43
Cost per day	4.68

Repairs:	
Labor	$ 247.95
Material	299.05
Tug and derrick	35.16
Total	$ 582.16
Total operation and repairs	$1,705.59
Cost per day	2.42
Total operation and repairs per day	7.10

Method of Measuring the Displacement of Material in Scow Barges. A method of measuring materials delivered on deck scows, described by Mr. Howard J. Cole in the *Journal of the American Society of Engineering Contractors*, is given in *Engineering and Contracting*, May 1, 1912, as follows:

The exact dimensions of the scow were measured by steel tape and the point *A′* plumbed up from *A*, see Fig. 18, similarly *B′*, *B″* and *A″* were obtained, and the distance *A′ B′*, *A″ B″*, *A′ A″*

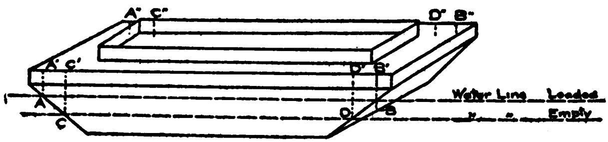


Fig. 18. Displacement Diagram of a Scow Barge.

and *B′ B″* likewise measured by steel tape; the depths *A A′* and *B B′* and corresponding depths on the other side of the boat were carefully measured by a graduated rule and noted on a sketch of the boat. When the latter was empty the point *C′* was plumbed up from *C*, *D′* from *D*, and again on the further side, and the four dimensions corresponding to the loaded measurements recorded. From a comparison of the depths (light and loaded), and with the complete measurements taken, the displacement was computed as hereafter shown.

The length *A′ B′* and *A′ A″*, and the other two corresponding measurements were obtained direct on the scow deck, and the depths were obtained by taking the difference between the readings loaded and light and the displacement thus figured.

By averaging the lengths *A′ B′* and *A″ B″* and multiplying by the width *A′ A″*, also averaging the lengths *C′ D′* and *C″ D″* and multiplying by the width *C′ C″* and multiplying the average of these two by an average of the differences between the load lines (*C′ C—A′ A*, etc.) at the four corners, the cubic feet of displacement is obtained, which multiplied by 62.5 and divided by 2,000, gives the displacement in net tons.

This can be expressed in a simpler manner as follows:

$$\frac{\text{Area of boat loaded water lines} + \text{Area of boat light water lines}}{2} \times \begin{matrix}\text{distance}\\ \text{between the}\\ \text{two planes}\end{matrix} \times \frac{62.5}{2{,}000} = \begin{matrix}\text{Displacement}\\ \text{in tons.}\end{matrix}$$

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CHAPTER XVI

METHODS AND COST OF TRENCHING

The words trench and ditch are often used synonymously, but as treated here each word has a distinct meaning. *Trenches* are long and comparatively narrow excavations in the ground that are partly or entirely refilled with pipes, conduits, or masonry, or are backfilled with the excavated soil or other suitable backfilling material. *Ditches* are similar excavations that are left open after being dug for the purpose of carrying or holding water. The methods and cost of constructing them are treated in Chapter XVII. Wide ditches are often called canals. Trenches are dug for sewers, water pipes, and conduits, and for foundations of retaining walls and similar structures.

The main items of work in trenching are (1) excavation, (2) sheeting (in trenches in caving ground), (3) pumping (in wet soil), (4) pipe laying, and (5) backfill. The fourth item does not strictly belong under the head of excavation. However, in pipe sewer trenches, the last one or two feet (in depth) of trench are generally dug by the pipe layers and is thrown back on the pipe already laid. Thus, as cost records are often kept, a small part of the cost of sewer trenching is included under pipe laying. In water pipe work, the trench is generally dug completely except for the bell holes before the pipe is laid. Bell holes are usually excavated after the pipe has been laid in the trench. In conduit construction the earth is almost invariably excavated entirely before the conduits are laid.

References. In my "Handbook of Cost Data" will be found methods and detailed cost of trenching for water pipe and sewers, accompanied by costs of pipe laying, etc.

Excavation by Hand. Hand excavation is the most common method of digging trenches but there are many cases in which hand work is resorted to where machine excavation would pay handsomely.

In trenches up to 6 or 8 ft. in depth the material is first shoveled from the trench to the surface, and then, as the spoil pile grows larger, it must be shoveled away from the edge of the trench. A good foreman will see that the material from the first few feet of trench is thrown far away from the edge. Attention to this matter will often eliminate a second handling of the excavated material. The distance from the trench at which the first portion of the spoil must be thrown may be approximately determined by multiplying the height of the trench by its width and dividing by 2. In trenches from about 6 to 12 ft. deep the material must first be thrown to a staging, thence to the surface, and finally shoveled back from the edge of the trench,

thus being handled three times. In trenches 12 to 18 ft. deep the material must be handled four times. The earth from trenches of greater depths should not ordinarily be removed on stages but should be handled in buckets by a derrick or other machine.

Methods of Excavating Trenches by Hand. *Engineering and Contracting*, June 2, 1909, gives the following:

Men should never be placed indiscriminately at work in a trench. After opening a section of a trench, especially where there is water, the most rapid digger should be placed first, then the next best and so on down the line. This will allow the water to run towards the lowest part of the trench and one set of pumps will suffice to handle it, as well as let the timbering or shoring be carried on in its regular order. If the men were placed indiscriminately the better men would carry their sections to a greater depth quicker than the poorer workmen, causing the water to settle in their pits, thus impeding the work and increasing the cost.

There are several methods of placing the men at work in a trench. The most common one is to have the men spaced only a few feet apart so that the foreman can watch them. Sometimes a certain number of men are detailed to do the picking while the rest are shoveling. This arrangement cannot be recommended, especially in narrow trenches, as the pickers often interfere with the shovelers, and in moving from place to place the pickers tramp over the loosened earth and compact it. At times a shoveler will be kept waiting for a man to do his picking. The better way is to let each man do his own picking and shoveling, unless the trench is wide enough for two men to work side by side, then, one man will loosen the earth, taking only a part of his time for this, and the rest of his time will be used up in shoveling. The men will also alternate on picking, thus "spelling" themselves, without loss of time.

The advantages claimed for this method of spacing men in a trench are (1) that the foreman can watch the men easier than when they are scattered, and (2) that the follow up work, such as laying pipe, can be kept close to the men excavating, thus keeping the amount of open trench at a minimum. The first reason should not be given consideration. The second reason is often a valid one. However, by reducing the number of men in the excavating gang, and increasing the amount of work done by each man, this can be overcome. This brings us to consideration of a second method of spacing men in a trench.

The trench or ditch is staked off in sections, according to its width and depth, 25 or 50 ft. long. These sections should al-

ways be short enough to be finished in a day, as it has a good effect on a man to complete a task in a day and not have to start on an old job the next morning. Then, too, in case of rain at night, the water can drain to the low part of the trench. By this method one man does his own picking and shoveling and he cannot interfere with another man's work. In a wide trench or ditch two men can be placed in a section to work side by side, or with a narrow trench a long section can be given to two men, the men working from each end of the section towards the center. Men working in pairs generally do better work than when working alone. The slow man will try to keep up with the faster man's pace, or if each work at the same rate, each spurs the other on to increased efforts.

In working men in sections, a stake should be driven at the end of each section and numbered, as 1, 2, 3, and so on. Each section should be of the same length, or contain the same yardage. This permits a record to be kept of each man's work, or if the men are working in pairs, of each team's work. Then the number of cubic yards excavated by each man is known for each day's work.

By this method it will be found that in a trench not over 4 or 5 ft. deep a man will average 10 to 12 cu. yd. in a 10-hr. day, while by the other method a man will seldom excavate over 8 or 10 cu. yd. This method can be effectively applied where the men are paid a bonus for yardage in excess of a specified daily amount.

Another method of placing men in a trench is to have one man excavating the first 12 or 15 in., with another man following taking out another layer, and so on down in layers until the total depth is obtained. The advantages claimed for this method are that the men do not interfere with one another, the amount of trench kept open is reduced to a minimum, and no matter at what time a rain occurs, the water will always run to the lowest point in the trench. However, this method, like the one first described, makes it difficult to obtain the best work from the men, and the same advantages can be obtained by the second method described.

Excavating a trench by layers in successive steps is to be commended, but in using the second method of spacing men in a trench, and giving them sections to take out, this method of digging a trench by stepping it down can be adopted for each section. Fig. 1 shows a longitudinal section of a trench to be 5 ft. deep and illustrates how it can be carried down in steps. It is evident that a man working by this method always has a small breast, both to pick and shovel against, except when he

starts his section, where for a short time he must pick and shovel from the top. With a small breast he throws down more dirt with his pick and he also gets a much larger shovelful, as he throws the dirt out. Then, too, stepping from one step to another and casting the material out from different depths rests

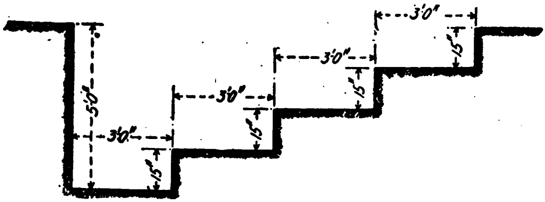


Fig. 1. Longitudinal Section of a Trench Showing Method of Excavating It in Successive Steps

the man without his stopping work. With this method, if it rains the water all goes to the bottom of the trench, where it can be quickly pumped out of each section.

Tools for Hand Trenching. Except in very shallow trenches or ditches, or in confined places where the action of a man is interfered with by the sides of the trench or by braces, a long handled shovel should be used. The workman not only conserves his energy because he does not bend down so often or so far, but he is able to cast the earth higher and farther than with a short-handled shovel. In sand or other easy soil a square edged shovel should be used. In firm soil or loam and in hard, compact earth or gravel, a round pointed shovel is preferred, but in clay a spade is far more efficient. A shovel holds a greater quantity of loose material than a spade, but clay generally holds together well and as great a quantity is held on a spade as on a shovel. The spade, moreover, is stronger and easier to drive into firm clay. For loosening the material a pick and not a mattock should be used. With a pick a much larger amount of material is loosened at each blow. A pick breaks out a pyramid while a mattock breaks out a truncated pyramid and one of smaller base and altitude. In the stiff Chicago clays a draw knife is often used to shave off pieces. In a stfff clay this is a more efficient tool than is either a pick or a mattock. In trenches the men should be prevented from dressing the sides of the trench. If given a mattock an Italian will trim the sides until they look as if sandpapered.

Cost of Digging Trenches by Hand on Long Island. The material in general consisted of 1 ft. of topsoil, 3 ft. of hard packed

clay requiring picking, and the remainder of fine sand and gravel. Nests of stones, averaging 1 ft. in diameter, were sometimes encountered. After the trench had passed a depth of 4 ft. a man was stationed on the bank to cast back the earth shoveled out by the bottom men. At a depth of 6 or 7 ft. a staging was generally required, and after passing a depth of 12 ft. a second staging was necessary. For slight depths the trench was braced with vertical plank held apart by Dunn braces, but when sand was reached sheeting was required. Stones were removed by a chain-hoist and small tripod. The last foot of trench was dug by the pipe layer and charged to pipe laying. The wages paid were as follows: Foremen, $4.00 per 10-hr. day; laborers, 17 ct. per hr.; waterboy, $1 per day. A proportion of the wages of foremen and waterboys is charged to the excavation. The following costs give the results of 48 time studies. From these observations it was found that in 10 hr. one man will excavate 9.23 cu. yd. in trenches up to 6 ft. in depth; 7.37 cu. yd. in trenches 6 to 12 ft. deep; and 6.38 cu. yd. in trenches 12 to 18 ft. deep.

Victor Windett, in *Engineering and Contracting*, June, 1911, states that one man dug 10.5 cu. yd. per day in trenches (in Indiana) up to 6 ft. deep; 7.2 cu. yd. per day in trenches 6 to 12 ft. deep; 3.7 cu. yd. in trenches 12 to 18 ft. deep; and 2.6 cu. yd. in deeper trenches. It would appear that pumping was required in all of the deeper trenches recorded by Mr. Windett, and this probably accounts for the low output at depths over 12 ft. On the Long Island work no pumping was required. The costs are given in the following table:

TABLE

Cost of Hand Dug Trenches; Depths up to 6 ft.; Material Handled Twice

Cost per cu. yd.	20.9 ct.
Cost per lin. ft.	11.4 ct.
Average cut	5 ft. 4 in.
Average width	33 in.
Average No. of men in gang	10.3

Cost of Hand Dug Trenches; Depths 6 to 12 ft.; Material Handled Three Times

Cost per cu. yd.	24.8 ct.
Cost per lin. ft.	21.8 ct.
Average cut	8 ft. 3 in.
Average width	34.4 in.
Average No. of men in gang	12.3

Cost of Hand Dug Trenches; Depths 12 to 18 ft.; Material Handled Four Times

Cost per cu. yd.	28.2 ct.
Cost per lin. ft.	46.8 ct.
Average cut	14.11 ft.
Average width	36 in.
Average No. of men in gang	14.3

A Platform for Retaining Earth, from Trenches. In a paper read before the American Railway Master Mechanics Association (1894) R. C. P. Coggeshall described a portable platform used to hold the earth from trenches. This platform consisted of ⅞-in. spruce boards secured to 3 x 4-in. joists. It was in two sections, each 6 x 12 ft., hinged so that one was horizontal and the other vertical, held in position by braces. This platform caused the laborers to take greater care when throwing up the earth so that it needed no rehandling, and also obviated the necessity of trimming the back slope to permit vehicles to pass. In backfilling, a certain amount of earth could be dumped by lifting the platform. Experiments on two 300-ft. lengths of 8-in. pipe trench, 5 ft. deep, showed that the cost of trenching, including cartage, with the platform was 14.7 ct. per lin. ft., and without it, 19.3 ct., a saving of 24%.

Cost of Sewer Trenches. J. G. Palmer gives the following cost data in *Engineering News*, June 25, 1908:

A sewer was built in 1905 from the new laboratories of the U. S. Dept. of Agriculture, Washington, D. C., across the mall to the public sewer at 13th St. The work was done by day labor (negroes) who are said to have been efficient and well managed, but it will be noted that they were excessively managed, for the item of "general expense" was inordinately high.

The trench was 3 ft. wide, except at manholes where the excavation was 6 ft. square. The ground was 10 ft. of clay, under which was 10 ft. of fine sand and loam, and below that was coarse gravel containing many boulders of "one man" size. No water was encountered. All excavation was done with picks and shovels. The trench was braced with screw jacks between 2 x 12-in. planks placed horizontally, and spaced 2 ft. c. to c. below the clay. The labor of bracing is included in the item of excavating.

An eight hour day was worked. The first section was 8.7 ft. deep, 3 ft. wide, 820 ft. long, and contained 4 manholes. The cost of the trenching was:

	Per cu. yd.
Excavation, laborers at $1.50	$0.50
Lumber at $18 per M.	0.08
Tools ($50)	0.06
Total	$0.64
General Expense:	
Foreman, at $5.00	$0.12
Clerk, at $1.50	0.04
Watchman, at $1.50	0.04
Waterboy, at $1.00	0.01
Carpenter	0.02
Total general expenses	$0.23
Grand total	$0.87

It will be noted that there was about 1 cu. yd. of excavation per lin. ft. of trench.

The second section was 23.5 ft. deep, 3 ft. wide, 838 ft. long, and contained 4 manholes. The cost was:

	Per cu. yd.
Excavation, laborers at $1.50	$0.68
Lumber at $18 per M.	0.03
Tools ($50)	0.02
Total	$0.73
General Expenses:	
Foreman, at $5.00	$0.08
Clerk	0.03
Watchman	0.03
Waterboy	0.02
Total general expense	$0.16
Grand total	$0.89

Cost of Trenching, Astoria, Ore. Mr. A. L. Adams states in *Transactions American Society of Civil Engineers* (1896) that in trenching for the Astoria (Oregon) Waterworks, in 1896, the first contractor averaged only 7 to 8 cu. yd. per man per day. Later on another contractor, even in the rainy season, averaged nearly 10 cu. yd. per man per 10-hr. day of trenching (including backfilling), at a cost (including foreman) of 17¼ ct. per cu. yd., wages being $1.70 a day. The material was yellow clay dug with mattocks and shovels.

Cost of Trenching at Holyoke, Mass. *Engineering and Contracting*, Sept. 16, 1908, gives the following account of concrete block sewers that were constructed in Holyoke during 1908, the sewer proper being built by contract and the excavation and backfilling being done by day labor under the direction of the city engineer.

This is a very expensive method of constructing small sewers, for two reasons: First, as in all kinds of construction work, day laborers employed by a government are very rarely as efficient as men working for a contractor. Second, in construction of this character, where the work of the trenchmen and the masons must be co-ordinated if economical results are to be obtained, it is necessary to have no division of authority or responsibility. By properly performing their respective duties trenchmen can save the masons much labor, and the masons can save much unnecessary trenching. It cannot be disputed that in almost every case there is a stronger incentive for the contractor's men to do efficient work than for the city's employees.

The following wages were paid for an 8-hr. day:

Foreman, per 8-hr.	$3.50
Laborers, per 8-hr.	$2.00

One trench was dug 14 ft. deep and 4.5 ft. wide, through sand and clay not a difficult material. The soil was thrown on the side of the trench and used for backfilling. There were excavated from this trench 2.33 cu. yd. per lin. ft. The cost per cu. yd. was $1.21, and the cost per lin. ft. was $2.82.

Another trench was 14 ft. deep and about 6 ft. wide, the material being the same as in the first trench. There were 3.11 cu. yd. per lin. ft. The cost of excavating and backfilling was $1.25 per cu. yd., and the cost per lin. ft. was $3.90.

Costs at Fredericton, N. B. From information furnished by A. K. Grimmer, City Engineer, and published in *Engineering and Contracting*, Aug. 25, 1909, the following data are taken regarding two pipe sewers built in 1908, at Fredericton, N. B. The work was done by day labor. Foremen received 30 ct. per hr. and laborers 18 ct. per hr. A 9-hr. day was worked.

Location	Waterloo Rd.	Phoenix Sq.
Length, ft.	495	811
Size of pipe, in.	8	8
Cut depth, ft.	9.7	5.8
Cu. yd. of excavation	533.5	522.5
Cost per cu. yd. excavation	$0.515	$0.374

The Waterloo Road sewer trench had to be close sheeted, the material being sand and the bottom 4 ft. wide. The Phoenix Square trench was in sand and loam and had to be braced every 4 to 6 ft. The material was dry.

The cost of sheeting and bracing is included in the above costs.

Costs of Sewer Work in Baltimore, Md. The following data are from the Annual Report of the city engineer of Baltimore, Md., for 1909. A more complete abstract of this report will be found in *Engineering and Contracting*, Aug. 3, 1910.

COSTS OF EXCAVATION ON VARIOUS SEWERS IN BALTIMORE

(For hand excavation except where noted, cost of bracing and backfill is included.)

	Per cu. yd.
Eastern Ave. sewer, 2,928 cu. yd.	$1.19
Eastern Ave. sewer, 1,624 cu. yd. (machine excavation)	1.46
Race St. sewer, 662 cu. yd.	1.25
Monroe St. sewer, 1,112 cu. yd.	1.08
Hollins St. sewer, 129 cu. yd.	0.64
Seventh St. sewer, 177 cu. yd.	1.36
Singluff Ave. sewer, 209 cu. yd.	1.12
University Parkway and Wickford Road drains, 527 cu. yd.	0.85
Clifton Park sewer, 961.6 cu. yd.	0.93
Cedar Ave. sewer, 732 cu. yd.	1.16

Water Main and Conduit Trenches. Trenches for water mains and conduits differ from sewer trenches in that the trench usually has a constant depth, which is relatively shallow.

Excavating for Electrical Conduits at Baltimore, Md. Chas. E. Phelps, Jr., Chief Engineer of the Baltimore Electrical Commission, is authority for the following data given in *Engineering and Contracting*, Mar. 11, 1908:

The figures show the cost of excavation from the inception of the work until June, 1907, a period of nearly 9 years. The cost includes all the labor, both men and teams, timbering drainage, clearing away of obstruction, such as old pipes, etc., and back-filling, but does not include paving. The wages paid to men and teams for an eight-hour day were as follows, foreman, 1899–1903, 37½ ct. per hr.; 1903 to 1907, 43¾ ct. per hr. Gang boss, 31¼ ct. per hr. Two-horse teams, 1900 and 1901, 37½ ct. per hr.; 1901–1903, 40⅝ ct. per hr.; 1903 to 1905, 45⅝ ct. per hr.; 1906 and 1907, 50 ct. per hr. One-horse cart used in 1899, 31¼ ct. per hr. Laborers, 20⅝ ct. per hr. throughout the 9 yr.

The excavation work was entirely in earth, which was sand, clay, the débris of filled in ground, and black mud on the streets near the harbor. The trunk lines of the conduits are mostly in the streets or alleys, but many of the distributing ducts are laid under the sidewalks, and frequently on both side of the street. In the low sections of the city many of the trenches had to be underdrained. These ditches needed shoring, likewise those dug through sand. But little timbering was done through the other materials, especially for the distributing ducts, which were uniformly about 3 ft. deep and 2 ft. wide, making about ¼ cu. yd. of excavation per lineal foot of trench, including the excavation for service and distribution boxes, which are from 60 to 70 ft. apart.

The trenches for the trunk lines are from 3 to 12 ft. deep, being on an average of 6 ft. and varying from 2 to 4 ft. in width, or an average of 3 ft. This means an average of 2–3 cu. yd. of excavation per lineal foot of trench, exclusive of manholes. These are so far apart, that the extra excavation will increase the average but little.

The per cent. of labor of the total cost varied somewhat for each year, running as low as 81% for the main trunk lines, where much shoring had to be done, and the trenches were wet, up to 97%, where little shoring was needed, averaging 95%. For the distributing lines the per cent. of labor of the total cost of excavation averaged 97%, varying from 94% to 98%. These percentages include labor, both men and teams.

It will be noticed that the price paid for teams and also for foremen has increased, yet, with the exception of the year 1903, the cost of excavation has steadily decreased. This, too, in spite of the fact that the amount excavated has decreased. This is due

primarily to the work of every year being farther and farther from the center of the city. In the central district of the city, the excavation is more difficult, owing to the pipes, sewers and other obstructions being larger and more numerous.

The cost of excavation also includes the cost of watching, this item being large, on account of the short working day, and the fact that two 8-hr. shifts must be made of the watching. This doubles the cost of this item.

Two horse dump wagons are used for hauling the excess material away from the trench. These wagons are of a nominal capacity of 2 cu. yd., but the average load is about 1½ cu. yd. place measurement. Each team averages five trips to the dump per day, thus hauling 7½ cu. yd. All work was done by day labor. The cost per cu. yd. of trench was as follows:

31,097 cu. yd. in 1899	$2.61
11,862 cu. yd. in 1900	1.87
7,155 cu. yd. in 1901	1.88
6,559 cu. yd. in 1902	1.82
11,590 cu. yd. in 1903	1.94
1,720 cu. yd. in 1904	1.97
15,476 cu. yd. in 1905	1.65
9,984 cu. yd. in 1906	1.53
5,687 cu. yd. in 1907	1.49

Trenching for Tile Drains. The following relates to work on an extensive scale at the experimental farm of the University of Minnesota. An abstract of a bulletin on this subject is given in *Engineering and Contracting*, Oct. 21, 1908. The tools used for this work are a skeleton or muck spade for removing the earth. This spade has a blade 18 in. in length, made of three prongs with a solid cutting edge at the lower end. A cut the full length of the blade is taken, the slice of earth cut being comparatively thin. The top of the spade is pushed slightly forward to break the cut loose. It is then raised and the material thrown out. The loose dirt which falls in the trench, known as crumbs, is thrown out by a long-handled, round-pointed shovel. The last cut of the spade reaches to within 2 or 3 in. of the grade line and is just wide enough at the bottom to admit the tile. The bottom is cleaned out and dressed to fit the lower half of the tile with the tile scoop.

The tile scoop is a long-handled tool, semi-circular in shape, 16 in. in length and made in sizes to fit the various tile up to 8 in. When over that size the finishing is usually done with the long-handled shovel. The tile scoop is operated by standing in the trench and drawing toward the workman. The bottom of the trench behind this tool is smooth and conforms to the lower half of the tile. In trenching by hand, unless the trench is deep, or

the digging hard, two men work together. One takes out the top spading, the other the bottom and finishes the trench. On deep trenches there is usually a man at work on each spading in depth, the trench being carried along in steps. Many tile ditchers throw the excavated earth on both sides of the trench, while others prefer to throw it all on one side; however, this is a matter of little importance in most localities.

The contract prices on a certain job involving the laying of 11,430 ft. of tile drain were arrived at in accordance with

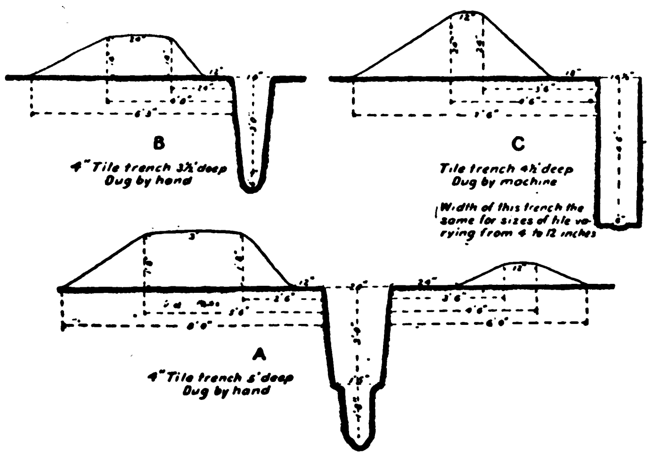


Fig. 2. Forms of Tile Trench on Experimental Farm of the University of Minnesota.

the common rule of tile construction, i.e., a fixed price for all trenches averaging 3 ft. or under in depth plus an additional sum for each inch additional average. The average is found by dividing the sum of the cuts at all the stakes by the total number of stakes. In this case the price was 40 ct. per rod for 3-ft. work, then 1 ct. for each additional inch up to 4 ft. work, then 2 ct. per inch for each additional inch. This gives prices for various depths as follows (cost of trenching, laying tile, and blinding, included):

3-ft. trenching, 40 ct. per rod or $2.42 per 100 ft.
3.5-ft. trenching, 46 ct. per rod or $2.79 per 100 ft.
4-ft. trenching, 52 ct. per rod or $3.15 per 100 ft.
4.5-ft. trenching 64 ct. per rod or $3.88 per 100 ft.
5-ft. trenching, 76 ct. per rod or $4.60 per 100 ft.

The average work done by one man per day was 100 ft. of 3-ft. trench; 95 ft. of 3½-ft. trench, and 80 ft. of 5-ft. trench. Unskilled labor cost the contractor $2 per day.

The cost of backfilling tile trenches by hand was as follows per 100 ft.

Trench 4.5 ft. deep, 3.75 hr. at 20 ct. per hr.	$0.75
Trench 3.0 ft. deep, 2.8 hr. at 20 ct, per hr.	.56
Trench 2.0 ft. deep, 2.0 hr. at 20 ct. per hr.	.40

The cost of backfilling by dragscraper was:

Team with driver 55 min. at 45 ct. per hr.	$0.42
Scraper holder, 55 min. at 20 ct. per hr.	.18
Total per 100 ft., trench 3.5 ft. deep	$0.60

The cost of filling 100 ft. of trench with grader was:

Two teams with drivers on plow, 6 min. each at 45 ct. an hr.	$0.090
1 man to hold plow, 6 min. at 20 ct. an hr.	0.020
Total per 100 ft.	$0.110

The cost of backfilling 100 ft. of trench with a plow was as follows:

2 teams with drivers on grader, 10 min. each at 45 ct. an hr.	$0.150
1 man operating grader, 10 min. at 20 ct. an hr.	0.033
Wear and tear of machinery	0.027
Total per 100 ft.	$0.320

The cost of plow and grader work is the average of all the ditches filled in this manner. They varied in depth from 2.5 to 5 ft., with an average of 3.5 ft.

Cost of Tile Drainage in California. The following from *Engineering and Contracting*, Oct. 13, 1909, is an abstract of Bulletin 217 of the United States Department of Agriculture. The cost of 2,300 ft. of 6-in. tile drains on the Dore tract in California was as follows, the excavation being in dry ground to an average depth of 4.5 ft.

Digging trenches and laying tile —	
92 days, at $2.50 per day	$230.00
9 days, at $3.00 per day	27.00
	$257.00
Filling trenches —	
Two men and team, 6½ days at $6.00 per day	39.00
Man with shovel in vines, 1 day at $2.50 per day	2.50
	$ 41.50
Total	$298.50

There were 2,300 ft. of 6-in. tile laid. All of this was in vineyard where the dirt had to be thrown away from the vines. In filling the ditches a filling scraper was used, and the vines interfered with this work considerably. However, the cost of filling this 2,300 ft., $41.50, gives 1.8 ct. per foot. The cost of digging the trenches and laying the tile was 11.2 ct. per foot. The tile cost 13.3 ct. per foot. This gives a total of 26.3 ct. per foot for tile and all work connected with laying it and filling the trenches. To this must be added 2 ct. for cable inserted in all tile, and 3.7 ct. for wooden sand boxes, making a total of 32 ct. per ft. Sand boxes were spaced 300 ft. apart, contained 215 ft. B. M., and cost $11 each.

Use of Derricks and Locomotive Cranes. These are used to a considerable extent on trench work. For small but deep excavations in crowded city streets a hand operated derrick is well fitted to the requirements. Such derricks must be of light weight and easily moved and set up. Where the trench is continuous and there is room for its operation, a small steam operated derrick is frequently mounted on rollers and carried along with the excavation. Its track may be directly over the trench, on the trench timbering or it may be carried along one side of the trench, provision being made in the timbering for the additional load.

A locomotive crane is of still greater value, owing to its speed and increased range of work. With a crane it is possible to carry excavated material for back fill back along the trench. Steam operated derricks and cranes are usually used on trench work to handle skips or bottom dump buckets that are filled by hand.

In this connection it should be remembered that the orange-peel bucket will excavate soft material very rapidly and that it will work well even after the shoring is placed in the trench. The material under the braces can be shoveled to where the bucket can pick it up.

Use of Dragline Excavators. These are not adapted to work in confined areas. A dragline bucket cannot be used to cut close to line nor can it be operated where immediate timbering is necessary. It is well adapted for the first rough work on fairly large trenches in the open, especially where these do not require shoring. The bulk of excavation on certain trenches for the cut and cover section of the Catskill Aqueduct was taken out by drag-lines. These were afterwards trimmed to line and grade by hand, the additional material being handled in bottom dump buckets by a locomotive crane.

Another machine which has been used with success in trenches

is a traveling swinging derrick, operating an orange-peel bucket. This machine moves on solid ground ahead of the trench.

Victor Windett, in *Engineering and Contracting*, June 5, 1911, gives the output with this machine on several jobs in Indiana.

With a ¾-yd. bucket, operated by a power swinging 56 ft. boom, the best day's work done was 920 cu. yd. excavated in 10 hr. This was in a trench sheeted by pile driving ahead of the digging. The braces were placed 8 ft. centers, as the depth of the digging required, in a trench 14 ft. wide by 12 ft. deep. The spoil in part was loaded on 3-yd. cars and in part dumped on the ground 50 ft. away. The soil was alluvial river deposit.

In excavating for the Plaquemine, La., lock approach there was used a 3-cu. yd. orange-peel bucket hung from a boom 85 ft. long and loading on flat cars on a trestle 20 ft. above the working level. This boom was swung by gravity. The earth was wet Mississippi river alluvium. This bucket was changed in favor of a 2-cu. yd. bucket because the larger bucket overloaded the machine. The 3-cu. yd. bucket would, at times, take loads of approximately 4½ cu. yd. heaped up over the bull wheel, which strained the timber framework.

The digger discharged its load onto flat cars on a trestle adjacent to the work. The average haul for a loaded train was approximately 400 ft. Two light engines would handle 3 cars. Unloading was done by a Lidgerwood plow working between stakes on the sides of the car. The 3-cu. yd. bucket would place a load on the cars in 55 sec. With delays due to all causes the average output of the machine was 1,320 cu. yd. in a day of 10 hr. The labor cost was $0.19 per cu. yd. of earth dug, including operating, maintenance, transportation of spoil and unloading. The maintenance of the trestle was a considerable item.

For trench work a ¾-cu. yd. orange-peel bucket is about as large as can be economically used, because a larger bucket requires too much room, and would also require the bracing to be spaced farther apart than 8 ft. centers; this would necessitate timbers too heavy to be handled easily by the trenching gang.

Cost of Trenching with a Derrick at Big Rapids, Mich. *Engineering and Contracting*, Sept. 8, 1909, gives the following:

A trench 4 ft. wide, from 14 ft. to 17.25 ft. deep, and 1,000 ft. long, was excavated for a 15-in. pipe sewer. The material was gravel and boulders. As much as 3 cords of stone were removed from 400 ft. of trench, many boulders requiring a 3,000-lb. chainfall to handle them. The gravel was treacherous and required two to three sections of sheeting with three or four rangers.

The first 4 to 6 ft. of trench were excavated by means of a drag scraper, fitted with inside bars and bail to enable it to cut ver-

tical sides. A team and driver did all this digging and backfilling. The remainder of the trench was excavated by a No. 1 Parker derrick. This derrick reduced the cost from 78 to 59 ct. per lin. ft., and the crew from 27 men required for hand work to 16 men with the derrick. The buckets held ⅙ cu. yd., and 61 to 68 buckets per hr, were handled by 4 loaders, 1 dump man, 1 derrick man, and a horse and driver. It required no more than 7 min. to move the derrick ahead 16 to 32 ft.

The daily cost of the work was as follows:

1 foreman	$ 2.00
1 scraper team and driver	3.75
1 man holding scraper	1.50
1 man dumping scraper	1.50
2 men pulling sheeting and carrying it ahead at $1.50.	3.00
1 man setting top section of sheeting	1.50
1 man tending derrick	1.50
1 horse and driver on haul line	2.50
4 men filling 2 buckets at $1.50	6.00
1 man laying pipe	2.00
1 pipelayer's helper	1.50
Total per day	$26.75

This gang completed from 46 to 54 ft. of sewer per day; this gives a labor cost of 58.2 ct. to 49.5 ct. per lin. ft. of sewer.

Deep Trenching at Brooklyn, N. Y. A description of the methods pursued in constructing the Green Avenue relief sewer, Brooklyn, N. Y., is contained in *Engineering Record*, Sept. 1, 1900.

This sewer was constructed of brick and was 78 in. in diameter. The invert was situated 35 to 40 ft. below street level. When the depth exceeded 35 ft. it was customary to tunnel. The soil was of loam with a preponderance of fine soil. A track of 15-ft. gage spanned the sewer and on this traveled a car carrying a derrick. This derrick was equipped with a 25-ft. boom, and the buckets of earth were conveyed by it to a dump car alongside the trench.

The trench was dug in sections 25 ft. long, 11 ft. wide and 4 ft. deep. Then the sheeting was started. A 4 x 10-in. ranger was placed at the bottom, and the sheet piling of 2-in. planks, 16 ft. long, was started. Two men with wooden mauls drove down this sheeting as fast as 6 men with shovels lowered the trench. The trench was excavated in 4 ft. benches, two men setting the rangers and sheeting as the work proceeded. The braces were of 4 x 10-in. timber, and after being cut exactly to length were set in place with one end a foot or two to one side of the proper position. The braces were later driven horizontally into place and wedged there. A cleat was nailed across the brace at each end before it was put in position in order to prevent the brace from falling down. (See Fig. 3.) Cleats were also nailed to the

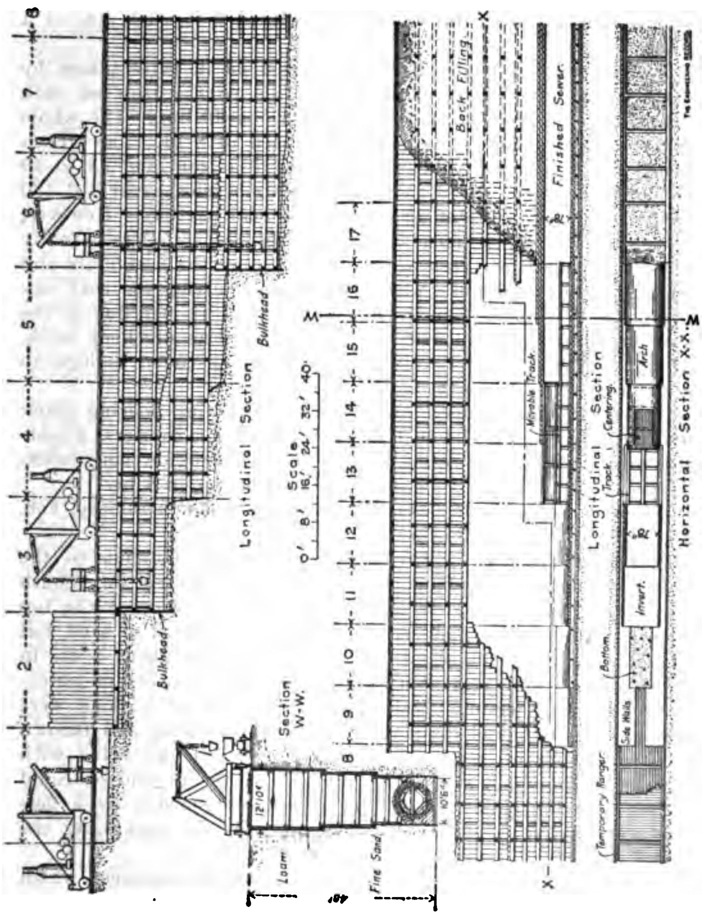


Fig. 3. Plan of Work on Green Ave. Sewer, Brooklyn.

sheet piling after it was down to grade in order to hold up the rangers. The rangers were all 25 ft. long, and were set with their joints opposite. Braces were 8 ft. apart except at the ends of the rangers: here the braces were placed 2 ft. each side of a joint.

Excavation and timbering were carried on in three places by three gangs of 12 men each, in addition to the man on each derrick, and 6 men on the dump and at backfilling. The whole force completed 25 to 30 lin. ft. of trench in 8 hr. The trench being 10.5 ft. wide at bottom, 13 ft. wide at top, and 35 to 40 ft. deep, the gangs of 36 shovelers and timbermen excavated 480 cu. yd. per day or about 15 cu. yd. per man per day. However, since one-third of the men were timbering, the shovelers actually loaded 20 cu. yd. per man per day. Including the backfillers and engineers, the total force was 45 men, and, putting the coal consumption as equal to 3 men, the equivalent of 48 men dug at the rate of 10 cu. yd. per man per day. This was excellent work. The trench was perfectly dry, the sand being moist enough to stand well on a face 5 ft. high.

The sewer gang proper comprised 2 men laying flooring plank and adjusting centers, 4 to 6 brick layers, 2 hod-carriers, 2 mortar mixers, 2 men lowering mortar and 2 men lowering brick. These 14 men laid 26 ft. of sewer (20,800 brick) in 8 hr.

Use of a Derrick and Cars. *Engineering and Contracting*, Feb. 28, 1912, gives the following:

A trench carrying a discharge pipe for an addition to the power plant of the Indiana Michigan Power Electric Co., South Bend, Ind., was excavated 30 ft. deep and 8 ft. wide at the top with a derrick. The materials encountered consisted of sand and gravel to a depth of about 10 ft., and clay to about 5 ft. in depth. With blue clay, containing occasional pockets of quicksand beneath, sheeting plank, 2 in. thick and 12 ft. long were used. The earth and clay were excavated by hand, and thrown into car bodies of ¾-cu. yd. capacity, V-shaped and fitted with legs, so that they would stand upright on the ground or could be used on the cars. These car bodies were hoisted by a derrick and placed on car trucks and run back for backfilling the trench.

The derrick was equipped with a stiff leg arrangement which would set on a portable frame straddling the trench, and was supported on a track, upon which it could be run back and forth over the work. The portable frame was built high enough to allow the cars to pass under it, the track for these cars was laid on stringers supported by the trench frame. Only one car truck was used, but 3 or 4 car bodies were kept in operation.

At the bottom of the trench a 42-in. concrete pipe was laid, and the earth was tamped in around it, nearly up to the center point. This was further backfilled to a depth of about 5 ft., at which depth the 36-in. pipe was laid and backfilled in the same manner. About 25 ft. of pipe trench were excavated and filled in a 10-hr. day, with a gang of 30 men.

Derrick and Orange-Peel on Louisville Sewer Work. *Engineering and Contracting*, Jan. 29, 1910, gives the following:

Fig. 4 shows a derrick owned by the American Engineering & Construction Co. of Chicago, used on one of their sewer contracts at Louisville, Ky. The work was the construction of a large concrete sewer 14 ft. in diameter and 4,230 ft. in length. The depth of sewer averaged 39.3 ft., and the average number of cubic yards of excavation per lineal foot was 26.5. In the beginning of the work a steam shovel was used for the first cut, but was abandoned as it was soon seen that the derrick could do the work required. The derrick took out the excavation to within 14 ft. of the bottom, and the balance was taken out with a Potter machine and carried back for backfill. The derrick was equipped with an orange-peel bucket. The spoil material was deposited in wagons and was hauled away under a sub-contract at 11 ct. per cu. yd. The rest of the material excavated by the derrick was dumped into Koppel cars, located alongside the trench and hauled directly to the backfill.

The derrick is a stiff leg, mounted on a portable turntable. The power plant consisting of a 30-hp. boiler and a 7 x 10-in. engine operating three drums, is mounted on the turntable in such a position as to balance the weight of the derrick and boom. The drums are equipped with two sets of gears permitting arrangement for a dragline bucket, if desired. The entire outfit cost about $6,500. The output of the derrick was about 63,000 cu. yd. and averaged 1,500 cu. yd. per week. The maximum output in one day was about 850 cu. yd. or 1,200 swings with the ¾-cu. yd. orange-peel bucket working in sand.

The derrick was formerly known as a Kearns derrick and the patents on the swinging arrangement are held by the Lidgerwood Manufacturing Co.

Trenching with a Grab Bucket in Wet Ground. *Engineering and Contracting*, Sept. 28, 1910, gives the following:

In trenching through sand for a sewer at Gary, Ind., a V-shaped trench with sides at the natural slope of the material is found more economic than a narrow sheeted trench. The depth of cut ranges from 3 ft. to 22½ ft. and averages 14½ ft., and from 2 to 3 ft. of the bottom is below ground water level, so that the conditions are such as would ordinarily be considered as

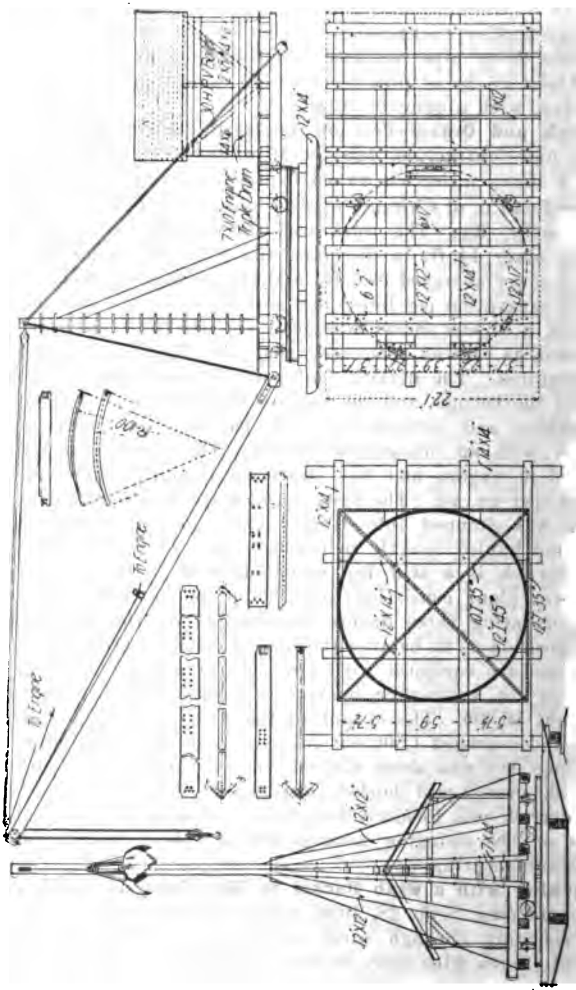


Fig. 4. Derrick for Excavating Sewer Trenches, Louisville, Ky.

calling for a sheeted trench. At Gary there were no restrictions on the allowable width of trench, as the work was through open country, and the decision as to methods rested entirely on questions of comparative cost. The contractor decided upon a method of bleeding the ground of the water by means of well points and opening a V-shaped cut of such width as might be necessary to get the depths required, using a grab bucket excavator. The result has been that the amount of excavation has been twice the volume required for a sheeted trench, but this 100% extra of digging has cost less than timber and sheeting labor would have cost.

Briefly, the method of work is to make a cut with a grab bucket operated from a derrick running ahead of the cut, letting the sides of the cut curve to slope. The grab bucket makes the cut roughly to grade. The next operation is to sink a row of well points on each side of the trench bottom and connect them with a pump; the ground water is drawn out low enough to permit the trench bottom to be trimmed and the sewer concrete to be placed.

The derrick is a rig built by the contractor of old timbers, and of such machinery as was at hand. The engine is 7 x 10-in., with vertical boiler. A swinging engine is also used. The machine rests upon a turntable, which in turn travels forward on rollers. When desired to move, a line is led out to a tree or stump and fastened; the other end is turned over a nigger-head on the engine and the machine pulled ahead as desired. The swinging of the boom is rapid and is accomplished by a cable which runs around the circular rail upon which the machine turns. The cable passes around this rail in the same manner as on the bullwheel of a derrick. An engineer and fireman operate the derrick. Two laborers prepare the ways for the rollers, and do the other necessary work around it, such as carrying coal and supplies.

The Andersen-Evans (Chicago) grab bucket is of a new type, differing from the ordinary clam shell buckets in that the differential drum is not fastened to an extension of the scoop but is carried by a separate frame. The scoops swing from hinges on this frame and when opened up an unusually wide opening is secured. The separation of the pivots gives an excellent cutting motion and it is especially noticeable that a full bucket of material is always secured when digging under water. This is unusual in such compacted material as sand under water.

After the trench has been excavated to grade by the grab and the material deposited on both sides, the pump men begin the installation of the well points. Two 3-in. pipes about 100

ft. long are laid along the trench, one on each side of the immediate area to be unwatered. A valve with two nipples is located at 4 ft. intervals all along these mains and rubber hose connections are made between the mains and the points. The points consist of 1¼-in. galvanized pipes, which are jetted into the sand at 2-ft. intervals. They have a metal point at the lower end and above the lower end for 2 ft. they are perforated with ⅛-in. holes and screened with fine wire mesh. It requires the time of 4 to 6 men to set these points ahead of the concrete work and to pull them after the invert has been put in. A small steam pump is attached to the 3-in. mains and the elevation of the ground water is lowered below the bottom of the sewer and the ground is trimmed to the circular shape fitting the invert.

The progress on the work for 10 days is an indication of the success with which it is being carried on. The average number of lineal feet of completed sewer (not back filled) was 93 ft. per day. The smallest day's work was 69 lin. ft. and the greatest was 124 lin. ft.

Trenching with a Dragline Excavator. The use of a dragline bucket for excavating a trench for a water main at Baltimore, Md., is described by J. C. Lathrop, in *Engineering News*, Nov. 19, 1914. The work on which this machine was used was a trench about 1,700 ft. long, the average depth being 15 ft., varying from 12 ft. at one end to 20 ft. at the other, and the width 18 ft. A dragline bucket with a capacity of 22 cu. ft. pulled up an incline by a hoisting engine, dumped into a bin and delivered to carts or wagons. The total amount of earth removed by this method was about 13,000 cu. yd., one-fourth of which was hauled away to allow for the space occupied by the pipe in the trench. The balance was piled up at one side of the trench to form an embankment upon which was placed track for a locomotive and for the locomotive crane used to handle the concrete pipe sections.

A drag-scraper bucket was used in place of a steam shovel because of the character of the material, it being necessary to sheet the bank as the excavation proceeded. Rangers or waling strips, 6 by 8 in. by 16 ft., were held in place and cross-braced by other 6 by 8-in. timbers. The sheeting were driven by two small steam hammers carried by blocks and falls, hung from steel cables directly over each line of sheeting. Steam for the hammers was supplied by the hoist engine boiler and a traction engine.

As high an output as 250 bucketfuls were removed in a working day at the average rate of a round trip in 2 min.

Trenching with Steam Shovels. Steam shovels have been used

for some years for trench excavation, and each year shows more efficient work done by them. When shovels were built of the old crane type they did not have as great an angle of swing as the present trench digging shovels have, with the result that the dirt was piled up so close to the trench as to interfere not only with the work of excavation but also with the other work that had to be done in the trench. The modern boom shovel was an improvement over the crane type, but the great improvement came in steam shovels for trench work when the full circle revolving shovel was introduced.

When the trench is of such dimensions that a small shovel can be used, revolving or full-swing shovels will prove much more advantageous than standard machines. Some of the principal advantages of the revolving type of shovel over the ordinary type are as follows: First, the revolving shovel can start a cut, moving gradually along until the required depth is reached, then turn around and excavate the "heel" that is left, whereas the cut for the standard shovel must be started by hand. Second, in the standard type of machine the steering wheels are in the rear, and some skill is required to steer the machine and keep it exactly over the trench, whereas with the revolving shovel the steering wheels can be placed at the front end. Third, where conditions are favorable, the excavation and backfill can be made at the same time. Fourth, with this type of shovel the excavated material can be kept well away from the trench and a large amount of material piled up on the bank. As the pile becomes high, the dipper of the shovel is used as a ram, pushing off the top of the pile of earth, and away from the trench.

Naturally, when the soil is sandy or in a material that has a tendency to cave, close sheeting and heavy bracing are required to enable the banks to carry the weight directly above them. When it is necessary to sheet directly beneath a shovel, digging must cease. This makes the percentage of idle time high, and the cost excessive in any but firm, hard ground. In ordinary soils a trench excavator will generally prove a more economical machine. On the other hand, in hard clay and boulders the steam shovel is a most effective tool.

As a steam shovel works into, instead of away from, the material it is excavating, it must be carried by the banks of the trench already excavated. The machine straddles the trench, being carried on heavy timbers lying transversely beneath it. With wide trenches, heavier, firmer timbers, or timber and steel platforms, must be used, and the shovel removed from its trucks and placed on rollers or on caterpillar wheels.

For trench excavation the regular length dipper arm is taken

off the shovel and a much longer dipper arm substituted. Trenches are dug with these long dipper arms from 14 to 18 ft. deep, while in a few cases they have been taken to a depth of from 20 to 22 ft.

Shovels meant for trench work vary in weight from 25 to 45 tons. Heavier shovels than these are apt to cave in the sides of the trench, and are difficult to move. Even a 45-ton shovel is often too heavy for this class of excavation. Such weight shovels are usually mounted on traction wheels, although they can be mounted on railroad trucks. However, for trench work heavy shovels are generally taken off their trucks and mounted on sills. Truss rods are not used unless the trench is wide. Timbers, or timbers that are trussed to give them additional strength, 12 x 12 in., are generally used for this purpose. Some contractors have made it a practice to build a platform across the trench and to place the shovel, mounted on its traction wheels, on this platform. This practice is wrong when the trench is very deep and of considerable length. The shovel is raised a foot or so higher than it would be were the wheels removed. However, when the shovel must often be moved from one stretch of sewer to another, it should be left on its wheels and sectional platforms used for supporting it above the trench.

In Fig. 5 the usual method of mounting a shovel for narrow trench work is shown. Heavy planks should always be laid down for the rollers to run on. It is generally well to have the rollers long enough to admit of two holes being bored through the ends so that bars can be used to straighten up the rollers when necessary, and also to move the machine by means of bars. However, the machine is not moved in that manner except when steam is not up. In Fig. 5, a small drum is shown beneath the machine. From this drum a hauling line is run to a dead man placed several hundred feet ahead of the machine, and the shovel is moved by its own steam by winding up this line on the drum.

The shovel roughly shapes the bottom of the trench, and the work is completed by a small gang of men working under the body of the machine. They cast the earth ahead so as to enable the shovel to remove it.

The shovel is mounted very low for deep digging. It is possible to carry the truss rods below the natural surface of the ground in trench digging, as they will not interfere with the work if they are properly placed on the timbers. When the shovel is to be moved over the ground from one trench to another, the whole frame can be jacked up and timbers placed over the rollers, thus raising the frame to such a height, so that the truss rods will not interfere with the ground as the shovel is

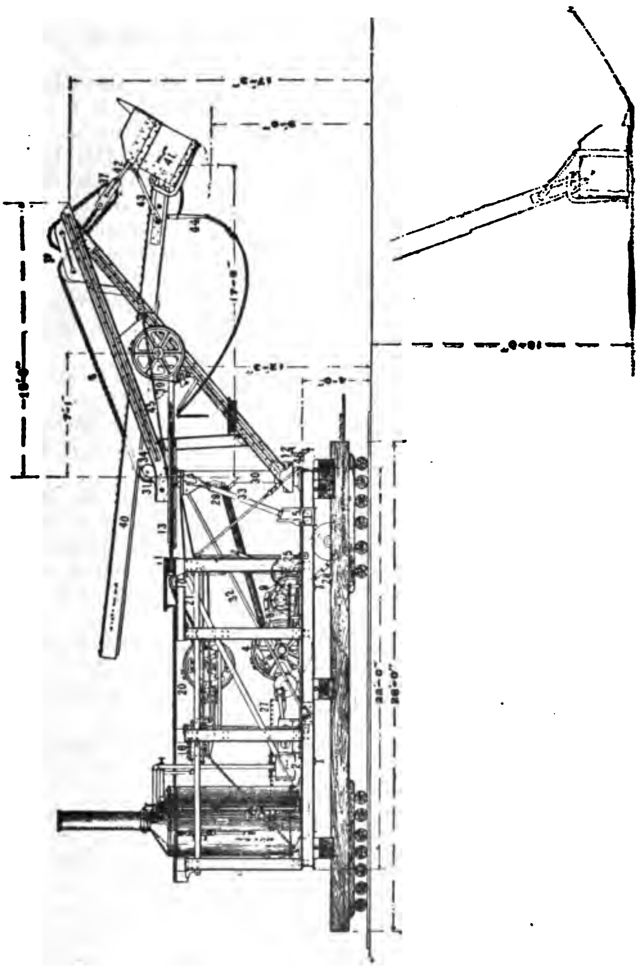


Fig. 5. Usual Method of Mounting a Steam Shovel for Trench Work.

moved. There is no reason, however, why heavy 12-in. steel I beams should not be used in place of the timber, thus doing away with the truss rods, and channel irons could be used on each side in place of the longitudinal timbers, thus allowing the shovel to be mounted lower.

Shovels of the revolving type are best for the excavation of narrow trenches. Instead of mounting the shovels on a skeleton frame, a platform can be built to hold the turntable, thus adding to the height. However, with steel beams, this height could be reduced. A good motto to follow is to keep the shovel low. No matter how the machine is mounted, arrangements should be made to hold the shovel in its position while digging, for in hard excavation, unless this is done the shovel will back away from the breast and much time is lost.

Additional Points in Using a Steam Shovel. *Engineering and Contracting*, July 19, 1916, gives the following: In digging large trenches, the following hints may be useful.

First.—Change the position of the levers that operate the shovel, placing them about 5 ft. outside the shovel-house, on an extension platform built for the purpose. Standing there the operator can see the bottom of the trench even where it is 25 ft. or more deep.

Second.— Remove the traction wheels and mount the shovel on rollers that rest on timbers laid on opposite sides of the trench. The shovel is shifted by means of a cable anchored to a deadman, and operated by the main engines. A 60-ton or 70-ton shovel can be moved on rollers 120 ft. per hour over level ground.

Third.— Ordinarily it is best to excavate a deep trench (18 ft. or more deep) in two "lifts" or benches. Work one day on the upper bench, then back up and work the next day on the lower lift.

In the upper "bench" use two 50-ft. I beams as "rangers" to support the "sheeting" of vertical planks. One I beam is placed horizontally on each side of the trench, about half way up the "lift," and jackscrew braces every 20 ft. hold the I beams and sheeting in place. Regular timber rangers and braces are also used, but some of these must be temporarily removed when the shovel is digging out the lower bench or lift, and then it is that the I beams hold the sheeting in place. When the shovel is shifted forward (15 ft. or so), the I beams are fastened to the shovel and moved forward with it, after loosening the jackscrews that hold the I beams apart. It takes about half an hour to shift a large shovel forward 15 ft. on rollers.

Sheeting and Bracing Under Steam Shovels. *Engineering and Contracting*, June 14, 1911, gives the following:

Sheet planking should be cut to the proper length as they cannot be driven but must be placed after the trench has been dug the full depth. When the shovel is carried on a permanent platform this serves as a convenient carrying place for the shoring also. If the banks will stand up without shoring it is cheaper to do that afterward. However, the pressure on the banks caused by a shovel is great, and no chances should be taken. In very treacherous ground the shoring should always be kept up close to the point of digging, but it is permissible to brace the trench temporarily and to put in the permanent shoring after the shovel has passed.

Bracing must be accomplished very rapidly or the shovel will be materially delayed. As soon as the dipper enters the trench for its last stroke the operator blows the whistle and the sheeting men prepare to act. When the upward stroke of the shovel is half completed these men quickly place the stringers and braces. The work calls for great speed as a cave-in may occur in a few seconds.

In some cases the trench is braced, in the portion being excavated, by two stiff steel beams with a cross brace at each end. The rear end of these beams is carried by chains hung from the frame of the shovel, and the forward end rests on the ground. These beams are used at a depth of 2 ft. or so below the ground surface. In moving these beams ahead the forward chain attached to them is caught over the dipper and pulled ahead by a forward stroke of the dipper, as in Fig. 6.

Sometimes, especially when the soil is soft and alluvial or in sand, the sheeting can be driven along the line of the proposed trench, and the material afterwards excavated with a steam shovel. The cost of steam shovel operations under such conditions was as follows:

In New Orleans, using a half-yard dipper 25-ton steam shovel over a trench 14 ft. wide and 12 ft. deep, 855 lin. ft. of trench, or 5,320 cu. yd. of earth, were dug in 55 hr. of work. The soil was alluvial river mud in an old partly drained cypress swamp, consisting of ¼ cypress roots and stumps. The sheeting for the trench sides had been driven ahead of the shovel and the bracing was carried on simultaneously with the digging of the trench. As the sheeting and bracing were a part of the permanent construction of the canal, a temporary set of stringers and braces was used for the operation of the shovel. The labor cost of this trenching, including the bracing, was 8 ct. per cu.

yd. To this expense should be added the expense of moving the shovel on and off the job, which amounted to 4 ct. additional, making the total cost 12 ct. per cu. yd.

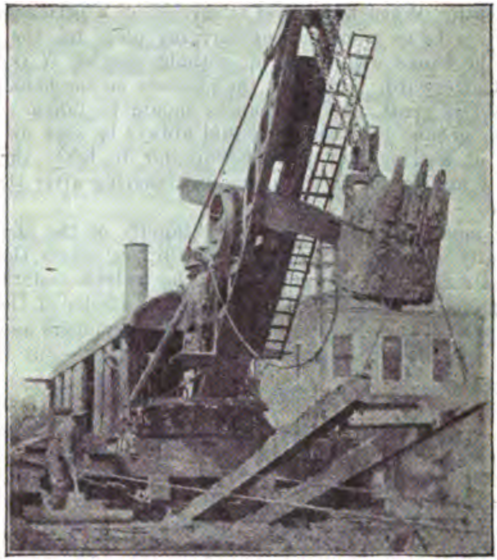


Fig. 6. Moving Steel Walings Used in Steam Shovel Trench Work.

In work in sand on Long Island steel sheet piling for small trenches excavated by a steam shovel was proposed. For this purpose the following tools and material were purchased.

600 pieces of No. 12 Wemlinger sheeting, each 10 ft. long, at 28 ct. per sq. ft.	$1,680.00
800 lin. ft. of 3 x 8-in. timber at $28 per M	44.80
100 extension braces at $1.00	100.00
200 ft. of marlin wound steam hose at 46 ct. per ft.	92.00
1 steam pile hammer	200.00
1 driving cap	10.00
Total cost of pile driving outfit	$2,126.80

The intention was to have the steam shovel furnish the steam required for power. Sheeting would then be driven in place ahead of the shovel by a pile hammer. This plan of work was

never carried out, because it was feared that with narrow trenches widths on curves, and with a caving soil, a steam shovel would prove an uneconomic tool. However, given wider trenches and better soil this method of driving piles might prove economical.

Method of Supporting Small Shovels. The following is from the *Excavating Engineer*, June, 1914, and Jan., 1915:

An 18-ton Bucyrus revolving steam shovel digging trenches at Washington, D. C., is illustrated in Fig. 7. This machine was equipped with a 27-ft. dipper handle, enabling it to dig to a depth of 18 ft. The dipper had a capacity of ⅞ cu. yd. It was fitted with five forged teeth, three on the front and one on each side.

The machine was carried on seven 12 x 12-in. timbers spanning the trench. These timbers were fitted with U-bolts and were moved forward by means of a chain-sling hung from the dipper. On the traction wheels of the shovel a double flange of riveted channel irons enabled the machine to travel on sections of rail. These sections were 3 ft. long.

An 18-ton, ⅝-cu. yd. dipper Bucyrus revolving shovel was used for excavating trench for a 36-in. water pipe at Cincinnati, O., during the fall of 1914. The shovel was carried on cross beams, joined in sets of two, resting on longitudinal stringers laid beside the trench. The traction wheels rested directly on planks laid on the cross beams. The trench was excavated 5 ft. wide and 7 ft. deep. The material was yellow clay and stony subsoil. The rate of digging averaged 300 lin. ft., or 390 cu. yd. per day, with a maximum of 375 lin. ft. in 10 hr. Although the dipper was not furnished with teeth, no difficulty was experienced in excavating this kind of material.

The pipe was usually handled by two traveling derricks, but where these could not be readily used, the pipe was handled by the shovel. Each section of pipe weighed 6,500 lb.

Cost with a Revolving Shovel at Auburn, N. Y. The method pursued in excavating 13 miles of pipe sewer trench at Auburn during 1919 is described in *Engineering and Contracting*, Mar. 2, 1910. The sewers varied in diameter between 5 and 24 in. Trenches were ordinarily dug 1 ft. wider than the diameter of the sewer. The average depth was 9 ft., and the greatest depth was 19 ft. The material excavated was clay and glacial drift, with embedded boulders. Pockets of quicksand were encountered at places. The upper 3 to 5 ft. were good digging, the remainder being difficult. The quicksand pockets and stonier parts that required blasting were excavated by hand.

Sheeting of 2-in. cull oak planks, set vertically, and braced

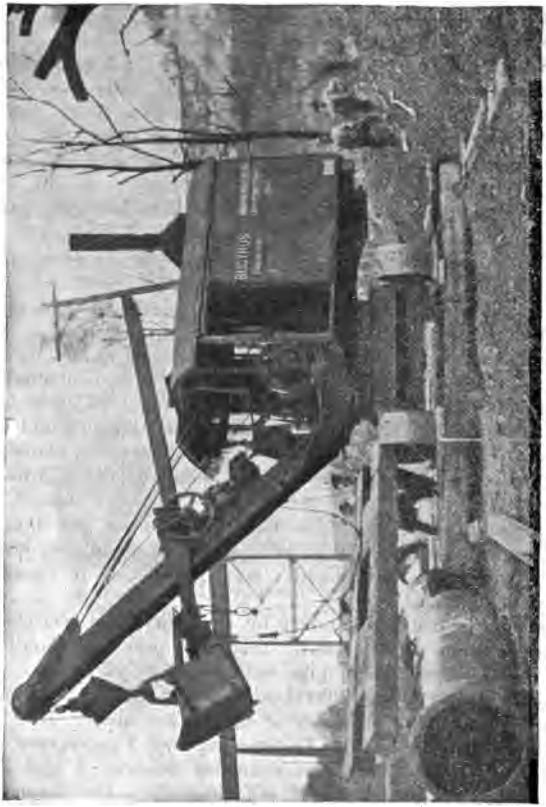


Fig. 7. Bucyrus Digging Trench for 36-in. Water Main.

with extension braces, were used in the quicksand and in wet places. About 3,000 lin. ft. of trench required sheeting.

The shovel used for excavating the major portion of the trenches was a No. 1 revolving Vulcan Steam shovel, weighing 35 tons, mounted on traction wheels, and equipped with a ¾-cu. yd. dipper and a 27-ft. dipper handle. This machine could dig to depths of 16 ft.

The timber platform used to support the machine was in three sections of a design similar to that previously described. Each move forward of the shovel occupied 4 to 5 minutes.

Pipe was laid directly beneath the shovel, and the material was used for backfilling as fast as it was excavated, the shovel making a swing through an arc of 180° and dumping the earth directly at the rear. When rock, boulders or other obstructions prevented the completion of the trench to grade, the excavated earth was piled alongside the trench and the shovel was not held up.

The crew required numbered 20. Assuming the rates of wages then current, the daily coal and labor cost was as follows:

1 engineman	$ 5.00
1 fireman	3.00
3 laborers placing track, etc., at $1.50	4.50
4 men placing sheeting	6.00
2 men placing extension braces	3.00
1 man carrying planks	1.50
2 pipe layers at $2.00	4.00
2 pipe handlers at $1.50	3.00
2 mortar mixers	3.00
1 instrument man	3.00
1,200 lb. of coal	3.00
Total	$39.00

From 90 to 125 lin. ft. of 4-ft. x 7-ft. deep trench, or 50 to 75 lin. ft. of 4 x 12-ft. trench were excavated per 8-hr. day. This gives a daily yardage of 90 to 135 cu. yd. excavated.

Steam Shovel Work in Milwaukee. In *Engineering and Contracting*, Feb. 26, 1908, Geo. E. Zimmerman gives the following. Mr. Zimmerman began using a Vulcan shovel for sewer work in 1903. He stated that a shovel paid best on trenches 4 to 10 ft. wide, and that he preferred a trench excavator for pipe sewer and water main work.

The shovel was mounted on traction wheels, and was carried above the trench on a timber platform. This platform was constructed of 6 x 8-in. x 16-ft. timbers laid across the trench with two "rails" of two heavy plank laid side by side with broken joints to form a track. In order not to delay the progress of the shovel, about 40 cross-timbers were required. This method of supporting the shovel is not as economical as the platform

used for similar work previously described. With separate cross-timbers it was necessary for the pitmen to carry about 8 timbers forward for each 8-ft. move.

The working force consisted of the following men:

1 engineman	$ 5.00
1 craneman	3.50
4 laborers at $3	12.00
Coal	3.00
Total	$23.50

About one-half of the time was spent in shoring the trench and moving the shovel ahead. The cost of digging depended on the nature of the ground. An 8 x 14-ft. trench, 2,200 ft. long, cost 38 ct. per lin. ft., or at the rate of 9.3 ct. per cu. yd. Mr. Zimmermann estimated that the same trench if dug by hand would have cost 61 ct. per cu. yd.

Steam Shovel Work at Wilmette, Ill. The *Excavating Engineer*, Oct., 1914, gives the following:

The trench for a concrete, elliptical, 6 x 9-ft. sewer near Chicago was dug by a Bucyrus 60-ton steam shovel. This machine was equipped with a 1.5-yd. special trench dipper, a 50-ft. dipper handle, and a 36-ft. boom. The shovel was mounted on heavy trusses spanning the trench and traveled on skids and rollers. The operating levers were carried on a special platform at the right hand side of the deck, thus enabling the operator to get a clear view of the trench being dug. The material was loaded into twenty-four 4-yd. dump cars, drawn in three trains by three 18-ton locomotives. The shovel was drawn ahead in 16-ft. moves by a cable attached to a deadman. At the end of each move the machine stopped long enough to enable the sheeting gang to sheet and brace the trench. The trench was dug to within 6 in. of the specified width and within a few inches of grade. Two men shaped the bottom of the trench with mattocks.

The sheeting was of vertical planks, with horizontal rangers held apart by wood braces fitted with pack screws. These braces were spaced 5 ft. apart.

The material was hauled back to the completed section of the sewer and used for backfill, the earth being dumped directly from the cars into the trench alongside.

Except for a soil topping the material was stiff blue clay, making very heavy digging. The trench was in general 22 ft. deep and 8 ft. wide. The rate of advance of the shovel was limited, however, by the speed of the concrete gangs behind. The average rate of digging was 5 to 6 moves, or 78 to 96 ft., or 585 to 729 cu. yd. per 9 hr.

Steam Shovel Trenching at the Chicago Clearing Yards. The

following data are from *Engineering Record*, August 2, 1902, and *Engineering News*, November 7, 1901.

The territory, about 4,000 acres occupied by the Chicago Transfer and Clearing Co., was drained into the Illinois and Michigan Canal by concrete sewers. The width of the necessary trench was 14 ft. at the ground surface for 90-in. sewers, and 7 ft. for 36-in. sewers. A 75-ton Vulcan steam shovel, with a 1.5-yd. dipper and a 36-ft. dipper arm, was used for excavating the larger trenches. A Bucyrus shovel with a ¾-yd. dipper was used for the smaller trenches. The sheeting and bracing were put in as the work progressed, the sheeting being composed of planks set vertically, and the bracing of extensible iron tubing. On some days the Vulcan output was double the average output given below. The deeper trenches were excavated by the shovels to a depth of 20 ft., leaving 2 to 4 ft. to be taken out by hand. Hand excavated material was loaded into buckets, raised by a swing-boom derrick, mounted directly over the trench. About 12 men in groups of 4 men each, loaded these 2-yd. buckets. A gang of 12 men, working in hard blue clay and carefully trimming for the invert, easily excavated the 4-ft. bottom layer of the 90-in. sewer for a length of 100 ft., in 10 hr. Very little picking was done. Round pointed, short handled shovels with foot-irons were most effective.

The backfilling was done entirely by a swing-boom derrick, straddling the trench and mounted on rollers, which operated a scraper. This scraper was made of the bowl of a wheel-scraper fitted with a bail and handles. The cable was endless, passing around the drum of a double-cylinder engine and through a sheave at the end of the boom, and served to draw the scraper backward and forward. Two men held the scraper while it was being filled. The machine with an engineman, fireman, and 2 loaders, backfilled 900 cu. yd. per day. No tamping was required. In trenches 12.5 ft. wide and 17 to 20 ft. deep the Vulcan shovel averaged 570 cu. yd. per 10-hr. day. In trenches 6.5 ft. wide and 11 to 14 ft. deep the Bucyrus shovel averaged 305 cu. yd. per day.

Steam Shovel Work on Chicago Sewers. In *Engineering and Contracting*, Feb. 11. 1914, H. R. Abbott gives the methods and costs of constructing large brick and concrete sewers in West 39th St., Chicago.

The total length of the West 39th St. conduit was 2,346 ft., of which 1,868 ft. was plain concrete and 478 ft. was reinforced concrete. The conduit was elliptical in section and 12 x 14 ft. in interior size. The concrete was from 12 to 20 in. thick.

Excavation was started at the Western Ave. end in open cut. A Bucyrus 70-ton steam shovel was used with 1¾-cu. yd. dipper. The shovel was mounted on five 16 x 18-in. timbers, 30 ft. long,

with two 2-in. truss rods to each timber. The top 4 ft. of trench was excavated about 3 ft. wider than the outside lines of the masonry, since no bracing, was put in near the top of the trench. Below this the trench excavation was made to the exact width of the masonry, plus an allowance of 4 in. for sheeting. Although a variation in and out was unavoidable, it did not exceed 2 in. in either direction. The trench width was 15 ft. 8 in.; average cut was 23 ft. 6 in., making an excavation of 13.7 cu. yd. per running foot. On account of the deep cut, the shovel was equipped with a 36-ft. boom and a 54-ft. dipper handle. As there was liability of slides and cave-ins, the excavation was handled in two lifts. On the first run the shovel excavated the top 10 ft., using 9-ft. sheeting with one set of bracing placed about 6 ft. below the ground surface. The shovel dug ahead of the finished cut from 75 to 100 ft., then backed up and excavated the lower 13½ ft.

The lower lift was taken out between steel beams, each built up of two 10-in. I-beams with cover plates, 50 ft. long, held in place by screw braces set 7 ft. back from each end. This replaces the ordinary wooden bracing and allows a free movement of the dipper in the trench for three moves or 36 ft. When a section is finished, the beams are carried ahead by the dipper, the wooden braces are replaced on the top sheeting, and another set of 9-ft. sheeting is placed with two sets of braces for the lower portion of the trench, the lower end of the sheeting being at a point where the invert curve meets the side wall. The lower sheeting back of the concrete was left in permanently. The bottom was trimmed and shaped by four or five bottom men, the material being cast ahead where the shovel could reach it. An iron frame or template built to the dimensions of the outside lines of the masonry was set up every 12 ft. as a guide in trimming the sides. The excavated material was loaded direct from the shovel on to 4-cu. yd. dump cars operating on a 3-ft. gage track. Ordinarily, the upper lift made the backfill, and the lower lift was run to a spoil area in McKinley Park, a haul of about ⅜ mile. The sheeting was 2 x 10-in. hemlock, the braces 8 x 8 in. and 6 x 6 in., with stringers 6 x 8 in. of yellow pine.

Concrete was mixed in a mixer mounted on timbers spanning the trench and delivering through spouts. The section contained about 2.5 cu. yd. per lin. ft. and a daily average of 75 cu. yd. was placed.

The average progress per day of 9 hr. was 30 lin. ft. for both shovel and mixer for the plain concrete section. This meant 420 cu. yd. of excavation, with disposal in backfill or spoil bank.

On the mixer platform was mounted a small boom derrick and

hoisting engine. This facilitated the removal of stringers and braces and pulled the mixer platform back and forth.

Backfill was made by 4-yd. dump cars, the track being shifted over the conduit as the filling progressed. The centers were left in until the sides were thoroughly compacted and at least 1 ft. of filling had been placed over the arch.

The force employed was as follows:

1 superintendent	$8.00
1 shovel engineman	7.00
3 dinkey enginemen	3.60
1 craneman	4.50
1 fireman	3.00
3 switchmen	2.25
2 flagmen	1.75
1 coal passer	2.50
3 foremen	4.50
1 hoisting engineman	5.60
4 bottom men	3.85
50 to 60 laborers	2.50
1 team	5.00
1 carpenter	4.80
1 machinist	3.50
1 machinist helper	2.50
1 office boy	2.00
1 material man	2.50
1 watchman	2.50
3 waterboys	1.00

The cost of trenching on two sections was as follows per cu. yd. of trench:

	A	B
Labor excavating	$0.188	$0.194
Plant excavating	0.046	0.046
Backfill	0.143	0.249
Disposal of waste	0.120	0.041
Coal	0.090	0.090
Total	$0.587	$0.620

In building 10,000 ft. of brick sewer (7 to 7.5 ft. diam.) on South 52d Ave., the average progress per day on the 7-ft. section was 45 ft., equivalent to 330 cu. yd. of excavation, while on the 7½-ft. section the average progress was 70 ft. per day, with 20 ft. cut or 500 cu. yd. of excavation per day. The difference in the progress between these two sections was partly due to the fact that the 7½-ft. sewer was built in a street 80 ft. wide, with open prairie on one side and unlimited room for work, and the 7-ft. section was built in a 66-ft. street with scant open space adjacent to the street.

Backfilling was done with a Monaghan revolving derrick, equipped with a Page orange-peel bucket, capacity 1 cu. yd. This is a very efficient machine for backfilling, but the operator should avoid dropping the load from any distance, as it is apt to

crack the masonry, especially when working during wet weather, when the backfilling is saturated with water.

Some special items may be worthy of mention, such as the cost of hand excavation in a sewer trench of this size, moving plant, etc.

In one case the steam shovel could not take out the bottom on account of the proximity of a viaduct. This earth was scaffolded out at a cost of $1.06 per cu. yd., being handled four times before it reached the spoil bank.

The cost of moving of the steam shovel a distance of 1,050 ft. across a railroad yard and over the tunnel section was $560, or 53 ct. per ft. This includes the partial dismantling of the shovel to pass under obstructions. At the start the shovel was taken off the railroad spur, moved ½ mile and placed on timbers to span the trench, at a cost of $750.

A Steam Shovel and Conveyor Plant. *Engineering News*, Oct. 11, 1894, gives the following:

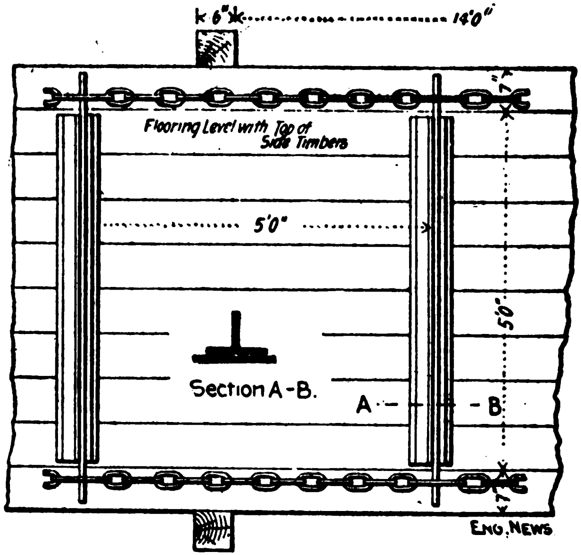


Fig. 8. Sketch Detail of Conveyor Floor and Scrapers.

In the construction of very large deep sewers a large part of the excavated material must be wasted and the remainder used

for backfill. For this reason it will often prove economical to dig sewer trenches of this type in two lifts or benches loading the material excavated from the upper lift onto cars for disposal in suitable places at a greater or less distance, and shifting the material as fast as excavated from the second lift to the completed part of the sewer for use in backfilling. These methods were pursued in the construction of the Wentworth Ave. trunk sewer, Chicago.

The Wentworth Ave. sewer is of brick with diameters of 5, 7 and 10.5 ft. for 6.5 miles, and diameters of 2.5 to 5.5 ft. for 3.75 miles. On the main portions the cuts were often very deep, ranging from 20 to 47 ft. in depth for a distance of 3 miles. The ground was very treacherous in places and for that reason and because of the great depth, special methods of excavation were required.

The excavation and backfill were performed almost entirely by machinery.

One steam shovel excavated the top soil to depths as great as 25 or 30 ft., loading the material onto flat cars on track directly alongside the trench. This track connected with the lines of the Illinois Central R. R., and the excavated material was removed to a distance and not used for backfill.

After the first cut had been completed piles were driven on 3-ft. centers, in two rows at the side of the trench and about 16.5 ft. apart. Timber lagging was fastened to the piles on the outer sides. When the removal of these piles did not bring too great a pressure upon the green masonry they were withdrawn upon the completion of the brickwork.

A second steam shovel on rollers travelled on 12 x 12-in. timber caps on the piles. This machine excavated between the rows of piles. The material in the deep cuts was soft, sticky blue clay. As the excavation deepened the side pressure tended to force the piles inward and the extensible iron braces often buckled. The material excavated in the lower lift was dumped directly upon a scraper conveyor operating along a track parallel to the sewer. This conveyor carried the material to the rear of the brick work, and dumped on to a cross conveyor or apron which led the material to the top of the completed sewer. Thus only one handling of the material was required.

The conveyor consisted of a stationary floor mounted on wheels and tracks, over which a series of scrapers passed. The scrapers were carried between two endless chains that passed over sprocket wheels at each end of the floor. These chains were operated from a power car at the head of the conveyor.

The conveyor worked satisfactorily. The speed of the masons

Fig. 9. Loading a Backfilling Wagon. (Note Chute, High Body and Door, also Method of Mounting Shovel.)

determined the rate of progress of the work and the machinery was often idle.

A Special Backfilling Wagon. The *Excavating Engineer*, Oct., 1915, gives the following:

Fig. 9 illustrates a 19-ton, ⅝-yd. dipper Bucyrus steam shovel, loading a backfilling wagon on trench work in Chicago. This shovel was mounted on traction-wheels and carried on wooden platforms spanning the trench. These platforms, six in all, were 24 ft. long by 36 in. wide. Fig. 10 illustrates their construction. They were made of two 12 x 12-in. timbers, 24 ft. long, armored on the inner faces by ¼-in. plates. They were separated by another 12-in. timber, 14 ft. long with the center cut away for the insertion of steel straps, on which was hung a ring for handling.

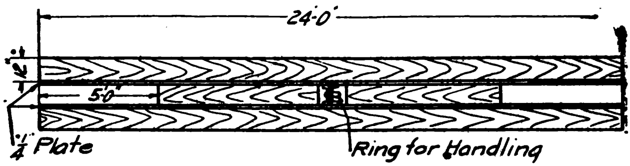


Fig. 10. Platform Used by W. J. Newman for Mounting Revolving Shovel for Sewer Work.

The work was done in the construction of a 5.5-ft. circular brick sewer on Canal street. The trench was from 14 to 20 ft. in depth, and 6 ft. wide. The material was tough blue clay with occasional boulders; a hard material to dig, but one which required comparatively little sheeting. The progress was from 60 to 85 lin. ft. per 10-hr. day.

The method of handling the backfill was unusually successful. Two wagons designed especially by W. J. Newman, consisting of an ordinary wagon truck on which was mounted a triangular box, the top of which was about 10 ft. above the ground, were used for this purpose. The floor of the box was a chute, starting at the top of the box and extending at an angle of about 45° a distance of about 3 ft. over the side of the wagon. This side of the wagon consisted of a hinged door controlled by a lever beside the driver's seat. Each wagon had a capacity of 3 cu. yd. The excavated material was loaded into this wagon and then carried to the point in the trench which was to be backfilled, where the door was opened and the material was chuted into place.

Besides the shovel crew there were 4 men in the trench shaping for the forms and handling the sheeting. These men assisted

in handling the platforms when moving forward. Two men were employed tamping backfill.

Rapid Work with Small Steam Shovel. According to *Engineering and Contracting*, Oct. 18, 1916, a Model 18 shovel, made by the Osgood Company of Marion, Ohio, made exceptional progress. The shovel which was equipped with a 19-ft. dipper handle and ¾-cu. yd. dipper is stated to have excavated a sewer trench 46 in. wide, 15 ft. deep and 150 ft. long in a 9-hr. day. The material consisted of very dry and hard clay mixed with boulders. After the pipe was laid the shovel refilled the trench. On another job this machine, similarly equipped, excavated a sewer trench 17 ft. deep, 9 ft. wide and 76 ft. long in 7½ hr., loading one-half of the material into wagons and depositing the other half on one side of the trench.

Steam Shovel Costs on Sewer Work in New York City. *Engineering and Contracting*, Dec. 2, 1908, in a long article on sewer construction in the Bronx Borough, N. Y. City, gives costs of steam shovel work on the Whitlock Ave. Sewer. A No. 2 Giant revolving trench shovel, made by the Vulcan Co., was used. It was operated by a crew of a shovel runner, cranesman, fireman and 4 ground men. A smaller crew than this could be used, but more efficient work is done with such a crew, and it is generally poor economy to attempt to save money by having a small crew in steam shovel work, except where the amount of excavation to be done daily is limited.

This shovel worked in a hard clay with a good many boulders in it, the boulders generally being smaller than ¼ cu. yd. A fair day's work in this material was about 300 cu. yd., working only 8 hours. The shovel on a number of occasions dug 250 cu. yd. in 4 hr., which is at the rate of 500 cu. yd. per 8-hr. day. The cost of running the shovel a day was as follows:

Shovel runner, at $175 per month	$ 6.65
Craneman, at $140 per month	5.40
Fireman, at $60 per month	2.30
4 laborers, at $2.25 per day	10.00
1,800 lb. of coal, at $3.50	3.15
Oil and waste	0.50
Interest, depreciation and repairs (estimated)	6.00
Total per day	$34.00

The cost of the plant was about $5,000, and the estimated item of interest, depreciation and repairs based on 200 working days per year, with an annual allowance of 24%. With an output of 300 cu. yd. per day the cost per cu. yd. was as follows:

Shovel runner	$0.022
Craneman	0.018
Fireman	0.008

Laborers	$0.033
Coal	0.010
Oil and waste	0.002
Plant	0.020
Total per cu. yd.	$0.113

This machine was moved over the streets, a distance of about ½ a mile. The time consumed was three days, the cost of moving being:

Shovel runner	$ 19.95
Craneman	16.20
Fireman	6.90
4 laborers	30.00
6 extra men	36.00
2,700 lb. of coal	5.22
Oil and waste	0.50
Total	$114.77

This means a cost of about $230 per mile moved. In moving the shovel long distances, it can be taken off its truss work and mounted on heavy, wide tread traction wheels, whereby the cost of moving is materially reduced.

Use of Steam Shovel on Curved Trenches. Richard T. Dana, in an analysis of trenching methods and costs, given in *Engineering Record*, May 23, 1914, is authority for the following costs on steam shovel trenching:

Trenches were dug for the purpose of laying sanitary and storm-water pipe of varying diameters from 4 to 36 in. of tile and concrete, and also for cast-iron water pipe from 4 to 12 in. in size. Nearly all of the work was on curves, since the sewer and pipe lines had to be between the curbs of the streets, and curved streets, while not economical to construct, were considered artistic and, therefore, desirable notwithstanding the extra cost.

The shovel was of the 25-ton, revolving type, mounted on traction wheels. The entire mechanism was under the control of the runner, and the shovel was fitted with a dipper arm and 1-yd. dipper specially designed for trench work, with an interchangeable boom capable of handling a small orange-peel bucket for cellar or stock-pile work. The platform upon which the shovel worked consisted of 12 timbers of 12 x 12-in. section, spaced 4 in. apart, and bolted together in sections of three. These twelve timbers rested upon planks laid upon the ground. On top of the timbers and running transversely to them, near each end, were planks upon which the traction wheels rested directly. To move up after a completed section had been sheeted, the shovel swung around and with a chain picked up one of the sections, and swung back again and placed it upon the planks which the laborers had laid ahead. Then after the plank track had been laid, the shovel moved forward under its own power.

In Table 1 the time given under "time worked by shovel" includes all time of moving up and waiting for sheeters before moving up, as well as the actual digging time of shovel. It is that time which could rightly be charged to the shovel. But when the sheeting gave out and the shovel was idle, as frequently happened during the experiment, such time was not charged to the shovel. This suggests one very important point, namely, always to have sufficient supplies and material on hand to prevent high-priced machinery from being idle.

At times considerable time was lost on account of caving banks. Curves caused a delay of 14% on one day and 50% on another.

TABLE I — WORK OF 25-TON REVOLVING SHOVEL — ONE-DAY PERFORMANCE

Kind of shovel	25-ton
Capacity of dipper	1 yd.
Length of move	4 ft.
Number of moves	20
Average time to sheet trench before moving up	9.2 min.
Average time to move up	4.5 min.
Time worked by shovel	565 min.
Cut	9 ft.
Width	36 in.
Material, clay and gravel that held up well.	
Remarks: Shovel idle while trench was being sheeted. Curve also caused idleness.	
Performance	80 cu. yd.
Unit cost, cu. yd.	22.6 ct.

Daily Cost of Operation

1 runner	$ 5.00
1 fireman	2.31
1 laborer	1.75
1 laborer	1.65
Supplies	4.50
Interest and depreciation, 17½% on $4,500 (approx.), based on 200 working days per year	4.00
Total	$19.21

$19.21 × 565/600 = $18.10; $18.10/80 = 22.6 ct. per cu. yd.

Process Analysis

	Per cent.
Actual digging	35.8
Delays: A — Sheeting trench before moving up	32.6
B — Moving up	15.9
C — Delay due to curve	15.7
	100.0

As a comparison with these results the work of another shovel on a straight trench in Chicago is given, showing that a steam shovel will do cheap excavation in trench if the section is large enough and the working conditions such as to warrant its use. The conclusion is drawn that steam shovels are not suitable on curved trenches.

TABLE II — DATA ON 70-TON SHOVEL AND PROCESS ANALYSIS OF ONE-DAY PERFORMANCE

Kind of shovel	70-ton
Capacity of dipper	2 yd.
Average length of move	15 ft.
Number of moves	4
Average time to move up	33¾ min.
Working time	602 min.
Cut	26 ft.
Width	16 ft.
Material: first 10 ft. top soil; next 16 ft. glacial drift.	
Performance	569 cu. yd.
Unit cost, cu. yd.	6.7 ct.

Cost of Operation

1 runner	$ 5.00
1 craneman	3.60
1 fireman	2.00
7 rollermen	10.50
Supplies	9.00
Interest and depreciation at 17½% on $9,000 (approx.), based on 200 working days	8.00
Total	$38.10

Unit cost per cu. yd. = 38.10/569 = 6.7 ct.

Process Analysis

	Per cent.
Actual digging	44.9
Delays: A — Waiting on sheeters	8.4
B — Moving up	22.4
C — Waiting on cars	23.2
D — Miscellaneous	1.1
Total	100.0

Trenching with Special Machines. The following machines are included under this heading:

Cableways and overhead or tram conveyors especially adapted to trench work. These machines do not excavate (unless used in connection with a grab bucket) but convey the excavated material.

Trenching Machines which excavate by means of buckets moving in the line of the trench. Excavators in which the buckets move across the line of the trench are used for open ditches and will be described in the following chapter.

Overhead Conveyors. From this class of machines I exclude derricks, land dredges, travelling cranes, travelling trench excavators, and similar machines which excavate as well as remove the material from the trench. Cableways, however, are included, even though a grab-bucket may be operated. In general overhead conveyors are those that do not actually excavate the soil, but convey it as well as the materials for the structure to be built in the trench.

Trench Cableways. One of the best known trench cableways is the Carson-Lidgerwood. For work in trenches over 8 or 10 ft. wide this machine possesses many advantages.

The main cable is stretched between towers 30 ft. high, which

stand 300 ft. apart, and one tub is handled at a time. This tub, holding one cubic yard, can be hoisted or lowered at any point between towers, and when empty can be swung to one side so as to accommodate a trench 30 ft. wide. It is often an advantage to have no part of the machine carried by the trench banks, since in soft ground banks may settle, and in rock they may be blown out. Under the cable there is no limit to the amount of waste or surplus material which may be stored over the completed work, there being no tracks to keep clear in order that the machine may be moved ahead. The hoisting engine and one tower stand upon a car which runs on a tee-rail track, but this is always on solid ground and ahead of the work, and the rails are taken up behind as it is moved forward. The rear tower stands on the ground and is taken down and carried to its new position when a move is necessary. The capacity of this machine may run as high as 350 cu. yd. per 10-hr. day, but for various reasons this capacity is seldom realized continuously. This complete outfit can be loaded upon one car, and weighs about 19 tons.

The price, in 1916, of a machine of 300-ft. span is $3,250, and one of 400-ft. span is $3,500. These prices include the services of an erector. These machines may be rented for $200 and $225 per month for the 300 and 400-ft. span machines respectively, plus the cost of freight, plus the wages of an erector at $4 per day.

Cableways are advantageous where the trench is very deep or more than 15 or 30 ft. wide, or where quicksand, or rock requiring blasting is encountered.

A Cableway on Sewer Work at Washington. From a report made by Frank P. David, published in the catalogue of the Carson Trench Machine Company, I have abstracted the following relative to the construction of the Easby's Point Sewer. The first 1,200 ft. of this sewer was in a cut from 12 to 40 ft. deep with 10 ft. of clay and rotten rock on top of solid rock. The blasting required heavy breaking, and in spite of careful work large masses outside the regular cross section slid into the excavation increasing the normal width of the trench from 18 to as much as 50 ft. in places. After excavating about 1,000 ft. of trench with steam derricks, a Carson-Lidgerwood cableway was installed. This cableway had a span between the end-frames of 300 ft. It was driven by an 8¼ by 10-in. engine. The hoisting speed was 250 ft. per min., and the conveying speed 400 ft. per min. The buckets had a capacity of 1 cu. yd. each. The width of the trench was 18 ft.

The material was cemented gravel and rotten rock. Wages were 35 ct. per hr. In an average 8-hr. day 280 cu. yd. were excavated. The operation expenses per day were as follows:

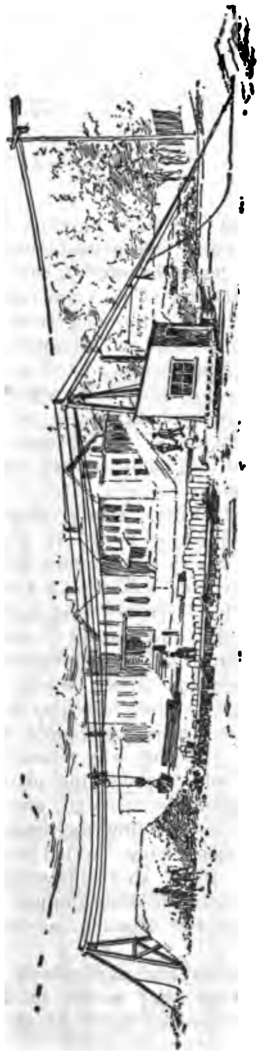


Fig. 11. Sketch of Cableway in Use in Orange, N. J., One of the First to Be Installed upon a Sewer Trench.

1 engineman	$ 2.00
1 fireman	1.25
1 signal man	1.00
2 dump men	2.00
Coal, oil, waste	1.50
Interest and depreciation (estimated)	7.00
Total daily machine cost	$14.75
Cost of picking and shoveling, 30 men at $1	30.00
Total daily cost	$44.75

The cost of picking, loading tubs, hoisting from trench 15 ft. deep, conveying 150 ft. and dumping into wagons was 16 ct. per cu. yd. Hoisting, conveying and dumping cost 5.3 ct. per cu. yd.

The Carson Trench Machine. This tram conveyor is especially adapted to trenches over 8 ft. deep and from 3 to 15 ft. wide. It consists of a rail supported on A-frames, carrying 4 to 8 tubs or buckets (each holding 1/3 cu. yd.) at a time. The legs of the A-frames or bents are provided with wheels that travel on a track, Fig. 12. The entire apparatus may be pulled ahead to a new position by its own engine. The prices of these machines ranged from about $3,000 to $3,500 in 1916, and they rented for approximately $200 per month.

Cost with a Carson Machine. *Engineering and Contracting,* Apr. 2, 1913, gives the following by A. W. Peters.

The work was a deep trench at Moundsville, W. Va.

The soil consisted of fine sand mixed with loam and unstratified yellow clay. In the shallow trenches this material could be excavated for a depth of 8 ft., and the ditch left open for several days in ordinary weather without endangering the banks, although in general verticals and trench braces were used. When the contractor opened up his deep ditches in this material he decided to use 8-ft. lengths of sheeting, placed without driving, in the excavated 8-ft. depth. In this way a section of trench 8 ft. deep would be excavated and the sheeting placed; then the next lower 8 ft. of material would be removed, and the second set of sheeting placed with its top butting up against the bottom of the upper section, the banks being carried down approximately plumb. In backfilling, 8 ft. of sheeting would be knocked out and the trench filled, the material being tamped against the trench side wall and not against the sheeting, as is ordinarily necessary.

Of course these conditions are particularly favorable to low sheeting costs, and all that that means in deep trench work, so that the results as derived in Table II should be considered in that light.

The material in these two sections was usually picked before shoveling into the buckets, as it could be handled more rapidly

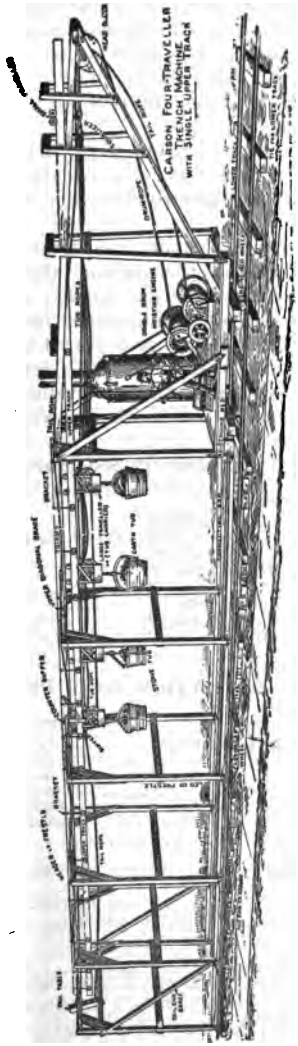


Fig. 12. Carson Four Traveller Machine, with Single Upper Track.

in that way. The general progress of the truck work seemed to be fairly good. The buckets were loaded rapidly, the best men being placed at this work. The machine was handled efficiently and the buckets were run back and forth at a fairly high speed.

Regarding the items of which the total cost is comprised a few explanations will be given:

The first 3 or 4 ft. of excavation were thrown upon the bank and not loaded into buckets. For the remaining depth two men shovelled into each bucket, usually loosening the material before shovelling.

The sub-heading "moving" under "machine" is made up principally of the cost of moving the machine along the ditch, which required tracklaying, anchorages and hitches ahead.

Coal cost 5 ct. a bushel at the mines nearby, or 7 ct. delivered.

Sheeting was 2 in. thick. Stringers were 4 x 6 in. in size. The cost includes placing, removal, and depreciation.

The tamping gang consisted of one shoveller and five tampers. The tamper was a piece of 4 x 6-in. timber, about 2 ft. long, with

TABLE I — QUANTITIES ON SECTIONS 1 AND 2

	Section 1	Section 2
Length	296 ft.	615 ft.
Depth	31 ft.	14–30 ft., average 22.1 ft.
Total excavation	1,529 cu. yd.	2,526 cu. yd.
Excavation per lin. ft.	5.2 cu. yd.	4.1 cu. yd.
Actual machine days	28	31
Excavation per actual machine day	55 cu. yd.	82 cu. yd.
Cu. yd. per man day	4.6	6.8

TABLE II — COSTS ON SECTION NO. 1, UNIFORM DEPTH

Item	Cost
Cost bucket loading, 1,529 cu. yd.	$ 559.80
Machine moving	$ 13.96
Machine engineer	80.40
Machine signal	52.60
Machine coal	18.00
Machine rental	300.00
Cost, conveying	$ 464.96
Sheeting	$ 231.42
Tamping	97.06
Teams	40.50
Pavement removal	15.12
Pavement replacement	41.20
Superintendent	138.45
Cost, miscellaneous	$ 563.75
Grand total	$1,588.51

This gives a total cost of $5.36 per lin. ft. or $1.03 per cu. yd.

an old shovel handle set in one end. Better results were secured with these wooden tampers than with iron ones.

Teams were principally engaged in removing surplus dirt and in evening up inequalities in trench depths.

The item of pavement includes much new 6-in. gravel base and many new brick.

The wages varied from $1.85 to $2.00, about 70% of the men getting $1.85.

It is commonly considered that the cost of operating a trench machine is substantially a constant amount per cubic yard of material moved, in a given kind of soil, regardless of variation between rather widely separated limits in depth of trench. The costs obtained from the Moundsville work indicate that cost varies with depth of trench. For the shallower trench from 14 to 30 ft. deep, the sum of the bucket loading and conveying costs was 52 ct. per cu. yd. For the trench of a uniform depth of 31 ft. the corresponding cost was 66 ct. per cubic yard. It may also be noted that the yardages handled per man per day were for the two trenches respectively 6.8 cu. yd. and 4.6 cu. yd. No other cost records that we have of trench machine work touch upon exactly this feature, and the present instance is therefore worthy of notice.

TABLE III — COSTS ON SECTION NO. 2, VARIABLE DEPTH

Item	Cost
Cost bucket loading, 2,526 cu. yd.	$ 639.89
Machine moving	$ 62.56
Machine engineer	100.33
Machine signal	58.25
Machine coal	10.20
Machine rental	416.00
Cost, conveying	$ 647.34
Sheeting	$ 117.06
Tamping	145.12
Teams	155.25
Pavement removal	52.42
Pavement replacement	85.00
Superintendent	175.19
Cost, miscellaneous	$ 730.04
Grand total	$2,017.27

This gives a total cost of $3.27 per lin. ft. or $0.81 per cu. yd.

The Potter Hoister and Conveyor Trenching Machine. This machine is illustrated in Fig. 13. It is constructed entirely of steel and is readily taken apart for shipment. It consists of a trestle of two longitudinal I-beams supported on bents spaced, as a rule, 16 ft. apart. These bents are mounted on wheels run-

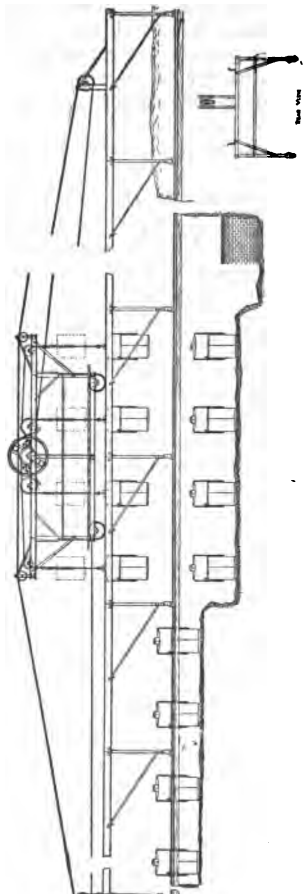


Fig. 13. Potter Improved Four-Bucket Hoister and Conveyor Trench Machine.

ning on rails on each bank of the trench. A carriage travelling on the I-beam tracks has sheaves over which runs the bucket hoisting rope. A double cylinder, 7 x 10-in., double friction drum engine is located at one end of the trestle. Two men ride on the carriage to handle the buckets. Buckets loaded by hand are lifted from the trench by the machine and carried back and dumped on the completed sewer.

Three sizes of this machine are in common use:

	Improved 4-bucket hoister and conveyor	Standard 2-bucket hoister and conveyor	Special 16-ft span hoister and conveyor
Bucket capacity cu. yd.	¾ or 1	½ of ¾	⅝
Track gage	8 ft.	5 ft. 5.75 in.	8 ft.
Bottom gage	10.5 ft.	10.6 ft.	16 ft.

The improved 4-bucket machine has a standard equipment of 17 bents or sections of trestle 16 ft. long, giving a length of trestle of 272 ft., and a total length of 290 ft. The equipment includes sixteen ⅝-cu. yd. buckets, a 20-hp. engine, 700 ft. of T-rail, cables, and complete fittings. The price is $4,500 (1916). The capacity of the machine is four loaded buckets handled at one time.

Excavation with Potter Machine at Brooklyn, N. Y. *Engineering News*, July 9, 1914, gives the following:

In the construction of a 15-ft. sewer in the Borough of Brooklyn, New York City, during 1914, a Potter trenching machine was used. The excavation was mainly in sand, and the earth was excavated by hand and raised in buckets, 12 of which were constantly in use. Two buckets were run back on the track and dumped into a hand-pushed 2-cu. yd. tip car, running on a narrow gage track laid on the planked-over trench bracing of the trench and backfill. The cars were handled and dumped by two men. The excavation amounted to about 30 cu. yd. per lin. ft. of trench. The machine handled about 250 cu. yd. per day of 8 hr., making a progress of 8 ft. of sewer per day, with a force of about 60 men. For the foregoing I am indebted to *Engineering News*, July 9, 1914.

Cost with Potter Machine at Chicago. *Engineering and Contracting*, April, 1906, gives the following:

Certain sections of an intercepting sewer were built by day labor in Chicago, during 1901–1903. A Potter trench machine 370 ft. long was used. An ordinary double drum hoisting engine was placed at the front end of the machine. By means of two cables and a series of drum sheaves, the engine hoisted the bucket and moved the carrier along the trackway as required. The entire machine, including the engine, was supported on track on

each side of the trench. After the track was built, 5 min. was ample time in which to move the whole machine 48 ft., that amount of trench being worked at a time. The Potter trench machine was used to remove the clay and about 2 ft. of overlying sand.

In the excavation six ¾-yd. buckets were used, four in the trench and two on the carrier. Two empty buckets were placed in adjoining sections and two full ones removed on each trip. The trench machine crew consisted of the following: One hoisting engineman, one fireman, and two carrier men. The number of bottom men or diggers ranged from 17 to 21, depending on the kind and amount of excavation. In addition, the track supporting the machine was built by a gang of timber men, whose other duties were the removal of braces, and miscellaneous work.

The rates of wages of the trench machine crew were as follows:

1 foreman at $4.00	$ 4.00
2 enginemen at $4.80	9.60
1 fireman at $2.75	2.75
2 carrier men at $3.75	7.50
17 bottom men at $3.25	55.25
Total daily labor	$78.10

One ton of coal, costing $2.90, per day was used; adding this to the total labor cost and we get $81. About 190 cu. yd. were excavated each day, so the cost, per cu. yd., was 40.2 ct. per cu. yd., exclusive of plant rental, and cost of laying track.

Cost with Potter Machine at South Bend, Ind. *Engineering and Contracting*, Jan. 29, 1908, gives the following:

During 1906, according to W. A. Morris, 2,444 lin. ft. of 5.5 and 6-ft. diameter sewer was built in South Bend, Ind.

The ground was flat and marshy, the material being loose black soil to a depth of about 4 ft., with sand and gravel in the remaining depth. The last 4 or 5 ft. was water soaked. The trench was 10.5 ft. wide and of 18 ft. average depth. The first 2 or 3 ft. was excavated by hand shovels or with plows and scrapers. The remaining excavation was mainly done with a Potter trench machine, which also handled the concrete.

This machine was 270 ft. long. About 200 ft. of trench was kept open at one time, the excavated material being used for backfilling. A sub-drain pipe was laid 30 in. beneath the grade of the sewer invert. The water entering this drain was collected in a sump, and then pumped out with a 6-in. rotary pump.

The wages paid per day were as follows:

Engineman on trench machine	$3.00
Fireman on trench machine	1.65
Engineman for pumping	2.00

Fireman	$2.50
Carpenter	2.50
Laborers	1.85

The cost of excavation and drainage was:

	Per cu. yd.
Pipe for sub-drain	$0.047
Labor laying this pipe	0.050
Pumping water	0.065
Excavation and backfilling	0.400
Setting and pulling shoring	0.150
Allowance for tools and general expense	0.035
	$0.747

There were 7 cu. yd. per lin. ft., so the total cost per lin. ft. was $5.22.

Cost of Excavating a Sewer with a Derrick and a Potter Machine. *Engineering and Contracting,* Oct. 9, 1907, gives the following:

Excavation for the Lawrence Ave. Sewer, Chicago, Ill., was performed with a derrick and a Potter trenching machine. The trench was 21 ft. wide and an average depth of 30.5 ft. The materials consisted of a top layer of black soil, 15 ft. of soft blue clay, 6 to 8 ft. of stiff blue clay, 1 ft. of sandy loam, and, last, about 2 ft. of hard blue clay that sometimes required to be blasted.

The first 16 to 18 ft. of excavation was done with the aid of skips and a derrick having a 55-ft. boom and equipped with a 7 x 10 double drum hoisting engine. The derrick was so arranged that the boom could swing in a half circle on either side of the trench. The framework carrying the turntables spanning the trench rested on shoe timbers, these in turn resting on rollers. A runway was built ahead of these rollers, and the derrick was pulled ahead by means of ropes, wound round the nigger head of the engine and single and double blocks. The skips, of 1 cu. yd. capacity, were filled by hand shoveling, lifted by the derrick and swung to one side of the trench, the spoil being used for filling low places, or later for completing the backfilling. As the excavation proceeded 2-in. plank sheeting was placed and carried down to a depth of about 14 ft., 8 x 10-in. timber spaced 20 ft. centers being used for bracing.

A Potter trench machine followed the derrick and skips, and was used in carrying down the excavation to the required depth. Six ½-cu. yd. capacity buckets were used with this machine, four buckets in the trench being filled, and two being carried back on the carriage and dumped on the completed brick work. The hardest part of the excavation was done with this machine, the clay being tenacious and coming away in hard lumps.

An average of 175 to 200 cu. yd. was excavated each day with this machine.

The wages per 8-hr. day and number of men employed in excavating with the Potter trenching machine were about as follows:

Engineer, $6.00	$ 6.00
Fireman, $2.50	2.50
1 man on carriage, $2.50	2.50
1 man on carriage, $3.25	3.25
20 bottom men, $2.75	55.00
1 man on dump, $2.75	2.75
Foreman, $3.50	3.50
Total per day	$75.50

Fig. 14. Model "C" Moore Trench Machine Co., Syracuse, N. Y.

One-half ton of coal was consumed each day by the machine. Allowing $2.50 for this, and assuming that the rent of the machine was $125 per month ($4.80 per day), the total cost per 8-hr. day would be $82.80. On the basis that 175 cu. yd. of material was excavated each day the cost would be about 47 ct. per cu. yd.

The Moore Trench Machine. C. N. Saville, in *Journal of New England Water Works Association*, Vol. 17, 1903, gives the fol-

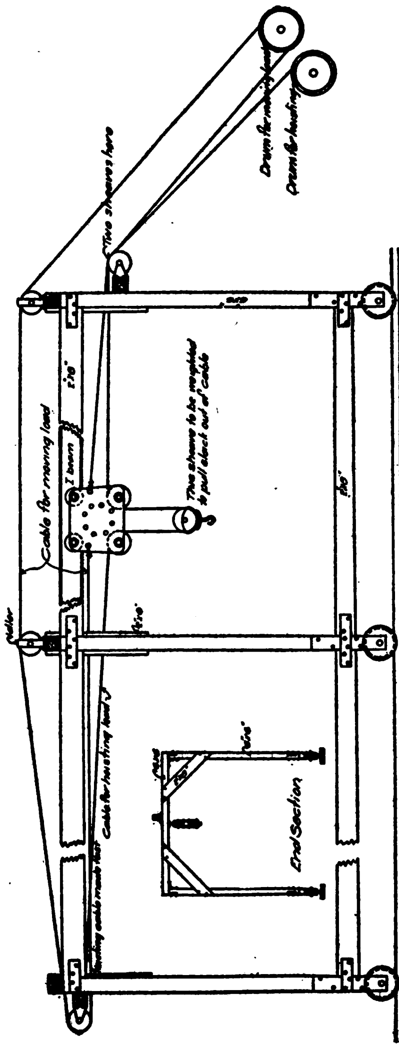


Fig. 15. General Details of Trench Machine Used at Jackson, Mich.

lowing. A Moore machine was very successfully used in the construction of a section of 48-in. pipe lines of the Boston water supply in 1896–7. With this machine no material was stored alongside of the trench, excepting the surfacing of the roadway. The material from the head of the trench was shoveled into buckets by laborers, hoisted and carried back by the machine to the completed pipe and there dumped. The buckets had hinged bottoms and the load could be dumped while the machine was in motion, or lowered to the bottom of the trench. In laying the pipes with this machine only about 11 ft. in width and 150 to 200 ft. in length of roadway was occupied at one time.

This machine in use at Syracuse, N. Y., is illustrated in Fig. 14. The apparatus is furnished in three models and sold for from $2,800 to $4,300 before the war.

Trenching with a Tram Machine at Jackson, Mich. *Engineering and Contracting*, Nov. 10, 1909, describes sewer work at Jackson, Mich., as follows:

Sewers, 4 to 18 in. in diameter, and about 2 miles long, were laid at Jackson, Mich. The soil was composed mainly of sand and gravel, with much water and running sand. The sewers were laid at depths varying from 7 to 25 ft. Tight sheeting was required.

Excavation for the first few feet was made with horses and scrapers. In trenches 8 ft. or less in depth the excavation was completed by hand. Sheeting was driven by hand and withdrawn with the aid of a chain block.

In deeper trenches, the machine shown in Fig. 15 (designed by the city engineer, A. W. D. Hall) was used. This machine was 150 ft. long, and, including three ½-yd. self-dumping buckets, cost $500. The traveller was operated by a double drum hoist, one drum hoisting the buckets and the other giving them a lateral movement. The excavated material was conveyed to the rear and used for backfilling.

The water was removed by means of an ejector. The force pipe of an ejector, shown in Fig. 16, was attached to the nearest hydrant, which gave a pressure of about 60 lb. The discharge pipe passed over a bulkhead into the completed sewer.

The sewer pipe was laid with aid of the machine. Where running sand or quicksand was encountered the special shield shown in Fig. 17 was employed. This shield consisted of three sides of a bottomless box. When near the grade the shield was set on the trench bottom with its open end straddling the completed pipe. Hay was then stuffed into the spaces between the sides of the pipe and the sides of the shield in order to keep out the muck. Two men inside the shield excavated to grade, driving the shield down as they progressed.

When excavation was completed the pipe was laid and jointed inside the shield, which acted as a temporary cofferdam.

The costs of work at depths up to 10 ft. varied widely. The cost of excavating 42-in. sewer from 17 to 20 ft. deep, was 53 ct. per cu. yd. At a depth of 26 ft. the cost was 75 ct. per cu. yd.

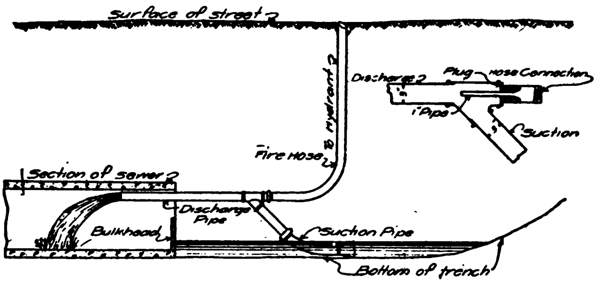


Fig. 16. Ejector and Method of Pumping Water from Sewer Trench.

These costs include excavation, backfilling, sheeting, pulling and driving, pipe laying, and cleaning up and grading the street after the work. They include everything except cost of pipe and cost of sheeting timber and, apparently, plant and overhead charges. The gang worked consists of 30 men; common labor is paid $2

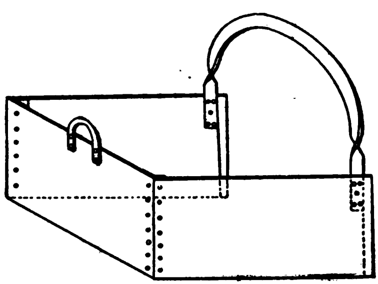


Fig. 17. Steel Plate Shield Employed in Laying Sewer Pipe in Quicksand.

to $2.25 per day, enginemen $3 per day and foremen $5 per day. The work is being done wholly by day labor.

The Parsons Trench Excavator. This machine has a series of scrapers and cutting teeth fastened on an endless belt travelling around a ladder. These buckets and scrapers are self-cleaning

TABLE I — PARSONS EXCAVATORS

Model	Width Trench	Depth Trench	Power	Number Cylinders	Size Cylinders	Size Boiler	Digging Speed	Weight
K-O	15.18, 24 in.	8 ft.	Gasoline	4	6 x 8 in.	....	1 ft. to 6 ft. per min.	22,000 lbs.*
K	22 in. to 42 in.	12 ft.	Gasoline	4	7¼ x 9 in.	....	1 ft. to 6 ft. per min.	28,000 lbs.*
K-O	15,t18, 24 in.	8 ft.	Steam	2	6 x 8 in.	48 x 72 in.	1 ft. to 6 ft. per min.	22,000 lbs.*
K	22 in. to 42 in.	12 ft.	Steam	2	7 x 8 in.	48 x 89 in.	1 ft. to 6 ft. per min.	28,000 lbs.*
E	28 in. to 60 in.	20 ft.	Steam	2	7½ x 10 in.	54 x 105 in.	6 ft. to 240 ft. per hr.	48,000 lbs.†
F	28 in. to 78 in.	20 ft.	Steam	2	7½ x 10 in.	54 x 105 in.	6 ft. to 240 ft. per hr.	52,000 lbs.†

* Parco traction only.
† Wheel drivers. Parco traction increases weight 6,000 lbs.
Electric power can be used if machines are properly equipped.

and deliver the excavated earth to a belt conveyor that carries the material to one side of the trench. These machines are made in two different models, and in two types of each model.

Models K and K-O are illustrated in Fig. 18. In the K machine the buckets travel automatically back and forth across the trench, thus cutting any width of trench between 22 and 42 in. without changing the size of the buckets. The model K-O is a very strong machine.

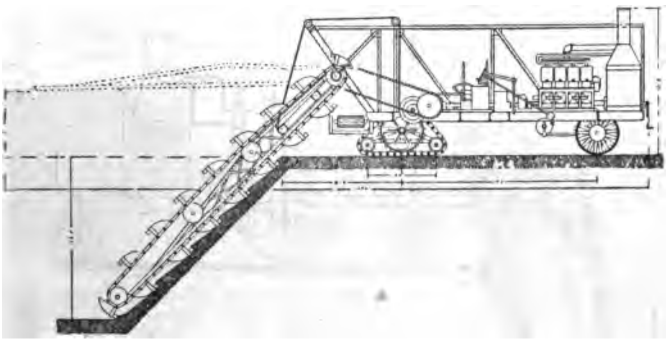


Fig. 18. Design of Parsons Excavators, Models K-O and K.

The daily cost of operating a $5,600 machine is estimated by the manufacturers as follows, based on a 10-hr. working day and 200 working days per year.

Engineman	$ 4.00
Fuel	6.00
Oil and waste	1.00
Repairs, 5%	1.40
Interest, 6%	1.70
Depreciation, 15%	4.25
Total	$18.35

The E and F machines are equipped with the oscillating device enabling widths of trench from 28 to 60 or 72 in. to be cut without changing the size of buckets. The advantages of these machines are their adaptibility to all sizes of work, their rugged construction, short length, variety of digging speeds, and, in particular, their almost vertical digging boom that enables sheeting to be placed within 4 ft. of the rear of the machine.

Steam driven machines require 1,200 to 2,000 lb. of coal per

10 hr. The first cost of machines is approximately $270 to $300 per ton of weight. These machines are made by The Parsons Co., Newton, Iowa.

Cost of Work with Parsons Excavator. W. G. Kirchoffer, in *Engineering and Contracting,* Apr. 10, 1912, gives the following relative to the work of a Parsons trench excavator in sand,

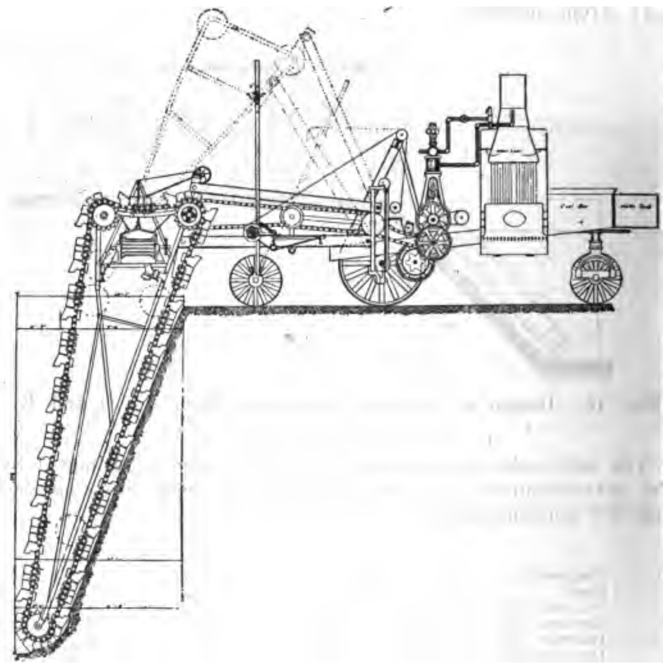


Fig. 19. Design of Parsons Excavators, Models E and F.

gravel and clay. The trench was 5,270 ft. long and was dug for an 8-in. sewer at West Salem, Wis. The trench averaged about 8 ft. deep. The total number of days' work put in on the job was 326, or an average of 61.8 days per 1,000 ft. of sewer.

The trenching machine was operated 20 days out of the total 26 put in upon the work, or an average of 263½ ft. per day. The least distance made in a day was 20 ft. and the maximum distance of 550 ft. of completed sewer. There were five days in

which the rate exceeded 400 ft. of sewer per day. The progress diagram is shown in Fig. 21.

The labor put in upon the work was divided as follows in days per 1,000 ft. of sewer:

Contractor	1.092
Inspector	4.935
Pipe layer	4.315
Foreman	4.270
Engineman	4.79
Fireman	4.412
Team	3.417
Mason	3.75
Water boy	1.993
Common labor	26.04
Tamper	4.13

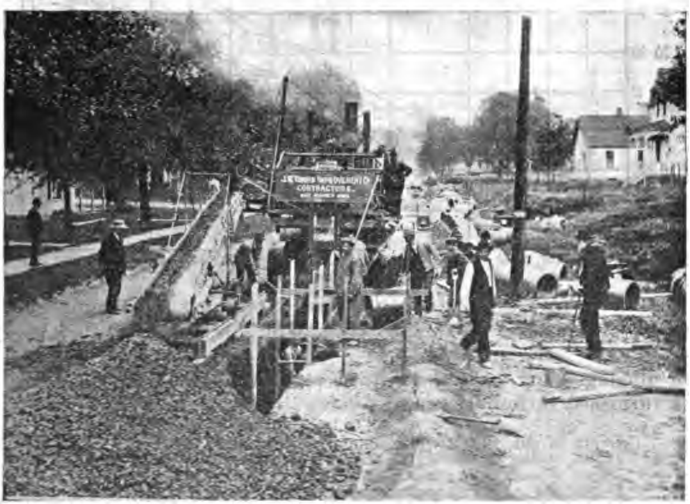


Fig. 20. Parsons Excavator Model F Equipped with Backfiller.

The greatest number of men employed in any one day was 16 and the smallest number was two. A man who was killed upon the work came in contact with some high tension wires in attempting to lift them over the excavator with a common broom stick when they were moving from one street to another.

P. & H. Trench Excavators. These are of two types: The wheel-type in which the excavating buckets are fastened to the rim of a wheel, and the ladder type in which the excavating buckets are fastened to a chain belt traveling up a ladder. The

principle of the wheel-type machine is illustrated in Fig. 22. This type of machine is furnished in two general styles. The drainage type machine is built in 12 sizes, ranging from the No. 1 excavator capable of digging trenches 11.5 in. wide and 7.5 ft. deep. The contractors type machine ranges from the No. 13 capable of digging 15 in. wide by 5.5 ft. deep, to the No. 36 machine capable

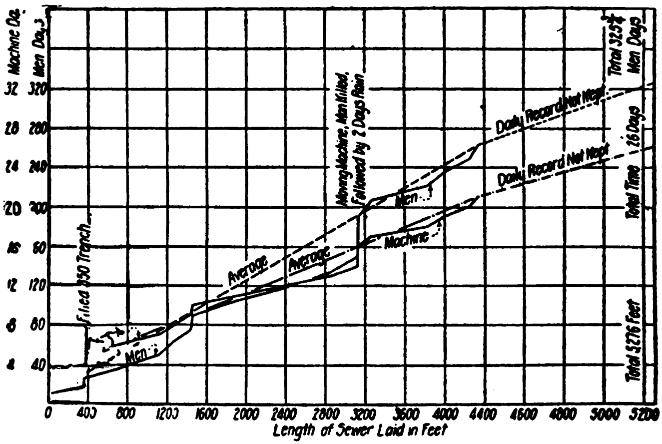


Fig. 21. Progress Diagram of Sewer Trenching by Machine at West Salem, Wis.

of digging 54 in. wide by 12 ft. deep. The ladder type excavator is furnished in four sizes: as follows:

Depth of cut, 10 ft.; width of cut, 18, 24 and 30 in.
Depth of cut, 12 ft.; width of cut, 24, 30 and 36 in.
Depth of cut, 15 ft.; width of cut, 24, 30 and 36 in.
Depth of cut, 20 ft.; width of cut, 24, 30, 36, 48, 60, and 72 in.

These machines are made by the Pawling and Harnischfeger Co. of Milwaukee, Wis.

Cost of P. & H. Machine Trenching for Water Mains. *Engineering and Contracting*, May 8, 1918, states that by using a trenching machine the Water Department of Erie, Pa., has overcome difficulties incident to the labor shortage and at the same time has effected a large saving in excavating for water main extensions. A report on the work of the machine, furnished by Mr. E. W. Humphreys, Superintendent of Waterworks, shows that it has dug 5½ and 6 ft. deep trenches at a cost as low as 0.9

ct. per lineal foot. This particular trench was dug in hard clay. The figure covers the wages of operator and helper and the cost of gasoline, oils and grease. In laying 10,000 ft. of 6-in. main in 1917 the cost of hand digging alone was 19 ct. per lin. ft., with common labor at 27½ ct. per hour. The hand dug trench was in clay with shale at the bottom.

The accompanying tabulation shows work done by the machine

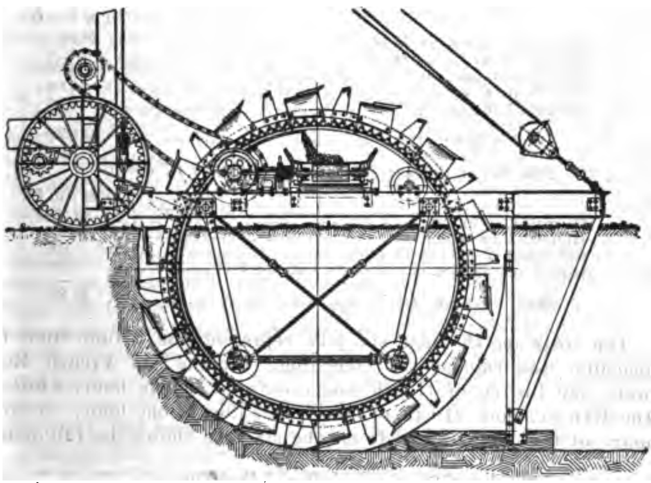


Fig. 22. Detail of Wheel and Method of Digging Ditch, P. & H. Trench Excavator.

at various times from May 1, 1917, to Jan. 3, 1918. The width of trench was 2 ft.

	Cost per lin. ft.
Rankin Ave. N., running sand and gravel	$0.065
Rankin Ave. S., hard shale	.036
22d W. Cranberry, hard clay	.010
28th W. of Sigsbee, clam loam	.010
Cherry N. of 30th, clay and gravel	.012
5th W. Raspberry, sandy	.014
27th W. Cascade, hard clay	.009
Old French Road, hard clay	.009

The costs given in this table are the actual operative costs, exclusive of overhead, depreciation and repairs, and pay of watchman. The costs in detail for three of the jobs follow:

Rankin Ave. N. (1,000 lin. ft. trench, 5.5 ft. deep)

	Per lin. ft.
Operator, 62 hr. at 32½ ct.	$0.0200
Helpers, 115 hr. at 30 ct.	.0345
Gasoline, 39 gal. at 24⅓ ct.	.0090
Oils, 4 qt. at 9½ ct.	.0004
Grease, 2 lb. at 1½ ct.	.0001
Total (1,000 lin. ft.)	$0.0640

Rankin Ave. S. (800 lin. ft. trench, 5.5 ft. deep)

	Per lin. ft.
Operator, 26 hr. at 35 ct.	$0.0114
Helper, 38 hr. at 28 ct.	.0130
Gasoline, 35 gal. at 25 ct.	.0109
Oils, 4 qt. at 11½ ct.	.0006
Grease, 1 lb. at 9 ct.	.0001
Total (800 lin. ft.)	$0.0360

28th W. of Sigsbee (652 lin. ft. trench, 6 ft. deep)

	Per lin. ft.
Operator, 3 hr. at 35 ct.	$0.002
Helper, 3 hr. at 27 ct.	.002
Gasoline, 12 gal. at 25 ct.	.005
Oils, 4 qt. at 11½ ct.; grease, 1 lb. at 9 ct.	.001
Total (652 lin. ft.)	$0.010

The costs on the last six jobs represent the actual time the machine was engaged in trenching. On the old French Road work 230 lin. ft. of trench was excavated in one hour, while in the 27th St. work 210 ft. of trench was dug in one hour. A summary of the operating costs on the six jobs shows the following:

6 jobs trenching (2,727 lin ft., 5.8 ft. deep)

	Per lin. ft.
Operator, 15 hr. at 39 ct.	$0.0021
Helper, 15 hr. at 31½ ct.	.0017
Gasoline, 61 gal. at 25.1 ct.	.0060
Oils, 13 qt. at 11 ct.	.0005
Grease, 5 lb. at 6½ ct.	.0001
Total (2,727 lin. ft.)	$0.0104

The trenching machine, a Pawling & Harnischfeger, was purchased by the Water Department early in 1917 at a cost of $5,650 f. o. b. Erie.

Cost with a P. & H. Trench Excavator at Erie, Penn. *Engineering News-Record*, Feb. 14, 1918, gives the following:

Four miles of 6- and 12-in. water-main trenches in wooded or frozen ground and with shale at the bottom were completed with a machine by the Water Department of Erie, Penn., between Feb. 1 and Oct. 5, 1917, at a cost far below that of hand work, even in 1915. Though at the speed developed by the machine, 3 to 3⅔ ft. per min. on 5½- and 6-ft. deep trenches, this repre-

sents less than two weeks' steady work, the difference in the amount paid for hand labor per foot in 1916 and in the cost per foot of all labor and fuel required with the machine represents more than half the first cost of the tool saved on the four miles already completed. It is doubtful if the extensions built in 1917, representing more work than was done in either of the preceding years, could have been completed without the machine because of the scarcity of labor.

The trenching machine, a Pawling & Harnischfeger, bought early this year for $5,650 f.o.b. Erie, is of the wheel type. The buckets are adjustable for cutting 11½ to 54 in. wide and trenches 4½ to 12 ft. deep can be dug. The machine is driven by a four-cylinder, four-cycle, 40-hp., gasoline engine. Ordinarily, one operator and one helper run it without other assistance under the supervision of the foreman who looks after the rest of the work. The trenches cut are 2 ft. in width and from 5½ to 6 ft. in depth. Clay 2 to 4 ft. deep, underlain by shale, is encountered on nearly all the work, though one trench has been dug in running gravel. Conditions are such that the machine cuts full length for the extension to be laid in a continuous operation, most of the trenches being less than 2,000 ft. long. The pipe gang of 7 men lays the new main behind it at the rate of a block, or 660 ft., a day. As the water mains are always extended in advance of paving, operations are completed by backfilling the trench with a team and scraper. In this manner 1½ miles of 12-in. and 2½ miles of 6-in. pipe were laid between Feb. 1 and Oct. 5.

During 1915, considered an ordinary year, the city laid 25,000 ft. of 6- and 12-in. mains in hand excavated trenches at a labor cost for digging, laying and backfilling of 29 ct. a foot for the smaller and 36 ct. a foot for the larger size. Much more pipe was laid in 1916 and this year because of the rapid growth of the city. While complete unit costs for the last year's work have not yet been compiled, it is known that rising wages caused considerable increase over those of 1915. Records for 10,000 ft. of 6-in. main laid at one time last year show a total labor cost of 37 ct. per ft., of which digging alone represented 19 ct., with common labor 27½ ct. an hour. The trench was in clay, with shale at the bottom. As compared with this, the first performance with the trenching machine, excavating for 1,620 ft. of line, was accomplished at a fuel and labor cost of 8.2 ct. per ft. for actual digging. This was in gravel which required sheeting, the cost of which is included in the above figure. On another occasion, in digging through cut-over land, where many large but partly rotted stumps were cut through, 682 ft. of trench was dug in four hours, at a cost of $7.55 for three men and 15 gal. of gasoline —

only 1.1 ct. per ft. On Oct. 5 the machine made its speed record of 660 ft. in three hours, $3.02 for gasoline and $1.88 for the wages of the engineer and helper being charged to the operation. This was about 0.75 ct. per ft. Both trenches were in shale at the bottom.

That these costs are typical of the work is shown by the record which the machine made on its most difficult bit of digging. Last winter, with 18 in. of ground frozen hard, it dug in one operation 7,220 ft. of 2 x 5½-ft. trench at an average speed of 3 ft. per minute. The bottom of this trench was in shale, the average depth of which proved to be 44 in. Over most of the trench the clay was frozen to the top of the shale.

This shale is not laminated clay, but a true shale, which can be picked in excavating bell holes, but which it pays to shoot when any considerable yardage must be removed by hand.

Excavating and Backfilling by a Carson Trench Machine. The following data are taken from *Engineering Record*, Jan. 2, 1915, relative to sewer work in Vancouver, B. C.

The machine is designed to be set up over a 340-ft. length of trench, from which excavated material is loaded directly into buckets, which elevate it, run back along the trench and dump it as backfill over pipe already in place. It is obvious that the pipe must be laid at the same rate as the excavation advances. The buckets are operated by cables running through carriers on an overhead rail, which is supported over the center line of the trench and 12 ft. above the surface of the ground by nineteen wooden trestles. Each trestle is mounted on two wheels, one on each side of the trench, which rest on the rails of an 8-ft.-gage track. This track carries the engine as well as the entire 340-ft.-length of framework, thus greatly facilitating moving ahead as work advances.

Excavation is carried on simultaneously in two 48-ft. lengths of the trench, a gang of six men working in each. The machine is equipped for handling six ⅕-cu. yd. buckets at a time, so that by keeping 18 buckets on the job, a set of empties is always left in the trench when full ones are removed, and the workmen need never wait while buckets are being dumped. Under this plan each man has an 8-ft. length of trench to work in, and fills his bucket independently of others. When loaded buckets are hoisted to the limiting position they are automatically locked to the carriers, which are then drawn along the overhead rail to the point where the fill is being made. Here the buckets are dumped separately by a lockman, who moves along the bucket line on a plank walk supported by the trestles. This lockman signals the engineer for each move, and is the only man required on the

bucket line, the empty buckets being taken from the cables and full ones substituted by the workmen in the trench bottom. The work of taking down the machine, moving to another job and setting up again ordinarily requires three to four days' time with a crew of 10 men. Thus with a haul of, say, 1 mile, the total cost of removing from one setup to another is about $170.

Canvas Troughs. When small trunk or lateral sewers were uncovered for any considerable length in excavating the trench, temporary provision was formerly made by carrying the flow during construction in open wooden troughs fixed to the side of the trench. It was found, however, that, besides being expensive to handle and move, these flumes interfered with the work and caused frequent trouble which could be entirely eliminated by the use of closed canvas troughs. The latter were made by simply affixing eyelets to opposite edges of a strip of heavy canvas of any desired width up to 3 ft. Eyelets on both edges of the strip are then hung on the same set of spikes driven into the timbering on the side of the trench and placed, roughly, on a fairly steep grade. This type of trough is often strung for the full 340-ft. length of the trench, and the laterals encountered are connected to it by short lengths of similar tubing.

Timbering Methods. A considerable quantity of timbering is taken from job to job with the machine, breakage being replaced as required. It has been found, however, that with the system now in use the breakage is almost negligible. For all classes of soft material 1½ x 10-in. sheeting is used in 4-ft. lengths, and it has been found that this works to much better advantage than the longer sheeting, which would require driving. When the trench has reached a depth slightly over 4 ft. digging is stopped while the timbering is placed.

The diggers all help in placing the timbering, at least until the stringers are braced in by jacks, after which excavation is resumed, while the man detailed to look after the timbering sets the struts and lines up the timbers generally. This man spends all his time attending the timbering, carries it forward as fast as it is removed from the backfill and lays it along the trench where it will be needed in new excavation. Thus, when a new set of timbering is required, all material is ready to be passed down by the timberman, and as the work-men do not have to leave the trench, the entire operation of placing timbering in a 48-ft. section 4 ft. deep delays the work only about 20 min. One 3 x 12-in. stringer is placed midway of each sheeting set, and opposite stringers are braced by 4 x 4-in. struts, spaced on 8-ft. centers. When nearing the depth at which sheeting will no longer be required the sheeting is changed from 1½-in. to 1-in.

material, which still further reduces initial cost and cost of handling.

Crew. Exclusive of supervision, 17 men operate the machine. These include 12 pick-and-shovel men filling buckets in the trench, one lockman, one engineer, one timberman, one toolman and a straw boss. Only half of the superintendent's time is charged against the machine, as he ordinarily looks after two jobs. In addition to the machine crew, a gang of four men is used in laying sewer pipe. Whenever the pipe crew gets behind with its work some of the diggers are set to helping with the pipe or concrete; and, vice versa, when the pipe crew has extra time it is used in the trench ahead. Thus it is possible to equalize any deficiency in forces or to compensate for unforeseen difficulties in either branch of the work, a flexibility which is considered a great aid to efficiency.

Cost Data. In order to give a fair idea of actual capacity of the machine and the cost of operation, a typical case has been selected in which about 7,700 cu. yd. were handled in a 2,700-ft. trench excavated for a 2-ft. trunk sewer. This work was done in Granville Lane, Vancouver, which has a width of 20 ft. A start was made on the lower end of the trench, hand labor being used until a depth of about 8 ft. had been attained. The machine was then put in service and used until the job was finished. The maximum depth of the trench was about 26 ft. The trench has a top width of 4 ft., which was maintained until a depth of 12 ft. 6 in. was reached, below which no timbering was used, and the width gradually decreased to 3 ft. at the bottom. The work was begun in the fall of 1913 and continued without interruption, using one 8-hr. shift. The average volume of excavation handled in 8 hr. was 45 cu. yd. A careful distribution of the costs on this work gives the following results:

	Per cu. yd.
Labor (including superintendent and watchman)	$1.63
Hauling machine to the job ($88)	0.0115
Erecting and taking down machine ($96)	0.0125
Upkeep of plant	0.0428
Running expenses	0.1126
	$1.81
Depreciation of plant	0.04
Interest on cost of machine at 5%	0.02
Total per cu. yd.	$1.86

The last two items in the table are values assumed for the city of Vancouver, and might be quite different under other circumstances. The life of the machine was assumed at 10 yr., it being assumed that in city service it would last much longer than in

ordinary contracting service, and 5% is the rate at which the city secures money for such purchases. It should be noted that only one haulage charge is made in these figures. This is because the machine is kept busy continually by being moved from one job direct to another. In contractors' service, if the machine were returned to the storage yard after each job, the haulage item would be doubled. The labor item, which is so large a proportion of the total, is based on the following labor costs per hour for an 8-hr. day: Pick-and-shovel men, 40 ct.; timberman, 42½ ct.; lockman, 42½ ct.; steam engineman, 53⅛ ct.; toolman, 37½ ct.; straw boss, 42½ ct., and one-half superintendent's time, 62½ ct. "Upkeep of plant" includes ordinary wear and tear, as well as minor breakages, while "running expenses" includes coal, water, timber, tool sharpening, etc. Two items which might have to be included under other circumstances are employer's liability insurance and excess spoil haulage — the latter in cases where excavation and fill could not be figured to balance.

The question of minimum trench depth at which the machine would be efficient has been worked out for Vancouver labor price as about 8 ft. for the usual case. However, if the job was comparatively short and the haul very long, a depth as great as 12 or 14 ft. might be the minimum. A feature that tends to make pick-and-shovel men efficient, or at least keep them all up to a uniform standard, is the fact that no one can do less than the others without having this known, since all six buckets come up at once; when one man is slower than the others he will still be working while the remainder of the crew wait. It is to be noted that in practice this generally works out so that after the first few days on a job there is remarkable uniformity in the time the men require for filling buckets.

The machine used in Vancouver was purchased early in 1911 for $5,000, duty paid, and was made by the Carson Trench Machine Company of Boston.

Cost with Austin Trench Excavators. Ernest McCullough gives the following data relating to work done by the "Chicago Trench Excavator," a machine made by the F. C. Austin Co. of Chicago.

The machine consists of an endless chain provided with cutters and scrapers which deliver the earth onto a traveling belt, the excavators and conveyors being carried by a four-wheeled traction engine, which furnishes the power.

In laying 7½ miles of pipe sewers at Marshfield, Wis., the daily cost of operating the machine and laying pipe was as follows:

Operator of trench digger	$ 3.00
Engineman of trench digger	2.75
Fireman of trench digger	2.25
Man trimming bottom of trench	2.25
2 men bracing trench with plank	4.00
2 pipe layers, at $2.50	5.00
2 men furnishing pipe and mortar	4.00
2 men tamping earth around pipe	4.00
1 man shoveling earth down to the tampers	2.00
2 teams and drivers scraping backfill	7.50
4 men holding the scrapers	8.00
Total labor per 10-hr. day	$44.75

About ¾ ton of coal was used daily.

The trench was 27 in. wide and averaged 7 ft. deep. The best day's run was 850 lin. ft. of trench, or 500 cu. yd. in 10 hr., in dry clay containing no stones. On another day nearly 500 ft. were run in spite of many stops to blast out boulders. A fair average was 400 to 500 lin. ft., or 300 cu. yd. per day. Due to the jarring of the ground by the machine it is necessary to brace the trench.

I am informed by Mr. McCullough that records of 650 cu. yd. per day have been made with this machine.

These trench excavators are made in four sizes to excavate from 14 in. to 60 in. in width and up to 20 ft. in depth.

As confirming these data of Mr. McCullough's, the following records given by Mr. B. Ewing are of value: In the summer of 1904, many miles of pipe sewers were built at Wheaton, Ill., by contract. Two Chicago (Austin) Excavators were used, cutting a trench 2½ ft. wide, 7 to 18 ft. deep. One machine would excavate 750 lin. ft. of trench 7 ft. deep through hard clay mixed with small stones, in a 10-hr. day. In cutting trenches 15 to 18 ft., a machine would average 150 to 200 lin. ft. per day, depending upon how much bracing was necessary.

Use of an Austin Excavator at Moundsville, W. Va. The following data are from a paper by A. W. Peters, in *Engineering and Contracting*, Feb. 28, 1912.

The work entailed the construction of 3.5 miles of trench 0 to 6 ft. deep, 16.5 miles 6 to 8 ft. deep, 3 miles 8 to 10 ft. deep, and 3 miles deeper than 10 ft. As labor troubles developed, and as the conditions were suitable to machine work, a No. 00 Chicago sewer excavator was installed. This machine was fitted with buckets 22 in. wide, and had a separate set of buckets 27 in. wide. The length of arm was 8 ft. but there was an extra 2 ft. extension that enabled the machine to dig 10 ft. deep.

The soil was excellent for machine work, consisting mainly of fine sand mixed with loam and unstratified yellow clay, moist enough to stand well with occasional vertical braces. Where sand predominated the machine had a large output, but where clay predominated the speed was much slower.

The backfill was divided into two operations: (1) Filling in and tamping by hand 1 ft. of earth covering. This cost about 16 ct. per cu. yd. (2) Filling in the remainder of the trench. This was done with a Sydney scraper and team. Tamping was accomplished by flushing the trenches with water from hydrants. Two men followed the scraper cleaning out the gutter and rounding off the fill. The cost of the backfill scraper work per day was as follows:

Team and driver	$ 4.50
Helper on scraper	1.75
Helper on hose, etc.	1.75
Cleaning up gutter, 2 men at $1.75	3.50
Water, 5,000 gal., at 10 ct. per M.	0.50
Per day of ten hours	$12.00

The average daily yardage of backfill was 280 cu. yd. at a cost of 4.4 ct. per cu. yd. The best day's work was 380 cu. yd.

The daily cost of trench excavation with the machine was as follows:

Operation:	
Superintendence	$ 1.50
Engineman and helper	4.75
Watchman	1.75
Coal, 15 bu. at 7 ct.	1.05
Water, 1 single team	2.50
Plumber, service pipes, average	1.00
Total per day	$12.55
Sheeting: Uprights and jacks; no rangers.	
2 men at $1.75	$ 3.50
Lumber, used repeatedly, neglected.	
Maintenance:	
Replacing dull spuds on buckets	$ 0.50
Engineman's time Sunday cleaning up, $3.00/6	0.50
Total maintenance	$ 1.50
Depreciation:	
Life of machine figured at 5 years, 9 months to the year, 25 days to the month	$ 4.00
Daily total (10 hr.)	$21.55

In 23 days 4,100 cu. yd. were excavated, at a cost of 12.1 ct. per cu. yd.; but the actual digging time was 203 hr. The best day's work was 321 cu. yd., at a cost of 6.7 ct.; and the poorest day's work was 82 cu. yd., because of bad banks, at a cost of 26.2 ct.

Cost with an Austin Excavator at Glencoe, Ill. *Engineering and Contracting*, Apr. 5, 1911, gives the following by Don E. Marsh, relating to a sewer system constructed at Glencoe, Ill.,

beginning August, 1910. The lengths and depths of the various sizes of sewers are as follows:

15,500 lin. ft. of 8-in. pipe, 8 to 12 ft. cut.
5,600 lin. ft. of 10-in. pipe, 7 to 13 ft. cut.
250 lin. ft. of 18-in. pipe, about 13 ft. cut.
1,000 lin. ft. of 15-in. pipe, about 16 ft. cut.
4,700 lin. ft. of 18-in. pipe, from very shallow to 30 ft. cut.

The soil, especially in the deep cuts, was hard clay, the top 15 ft. being a brownish clay with some traces of sand, and the remainder a hard blue clay. During the fall and winter months this soil became extremely hard and difficult, and could not be dug by hand without the aid of a pick. This was an advantage in some respects as it obviated the need of sheeting. During part of the work there was frost in the ground to a depth of 14 to 16 in.

A small amount of the excavating was done by hand, but the greater quantity was performed by two Austin sewer excavators. The large machine dug trenches 33 in. wide and up to 25 ft. deep. Before digging trenches of originally greater depth than 25 ft. the street was graded down 3 or 4 ft., and the remaining foot or two left by the machine in the bottom of the trench was excavated by hand, the dirt being thrown on the boom of the excavator or on the completed pipe line. The smaller machine dug to depths as high as 15 ft. The sides of the trench were left vertical and smooth. Vertical planks 13 ft. apart in deep trenches and less in shallow cuts, with extension screw braces, were used for bracing. At only a few points was caving experienced.

The cost of backfilling was excessive, as it was done by hand. An automatic backfiller was tried, but as this makes it necessary to keep the pipe laid close up to the boom of the machine its use was abandoned.

From records of a few average days the cost of labor in trenches 25 ft. deep was about as follows, with an average progress of 80 lin. ft. per day, or 200 cu. yd.

1 foreman	$ 8.00
Excavating machine, including operator	40.00
1 engineman	4.00
1 fireman	3.00
5 trenchmen at $3.00	15.00
20 laborers, backfilling, at $2.50	50.00
2 teams at $6.00	12.00
Coal	5.00
Repairs and sundry expenses	10.00
Total per day	$147.00

This is equivalent to $1.86 per lin. ft., or about 73 ct. per cu. yd.

Work of Austin Excavator in Shale. The following data give the comparative costs of trenching for 36-in. pipe through fairly hard New Jersey shale. The material was of such nature that it could be picked and shoveled. The total cost of trenching, laying, calking, and backfilling, including the cost of small tools, plant charges, etc., except the pipe itself, for 7 miles of 36-in. pipe was $1.10 per foot. Records taken of the cost at various times gave the following results:

Work during two weeks of 8 working days in September, trench 4 ft. wide by 6 ft. deep, total pipe laid 2,412 ft., an average of 301 ft. per working day. The cost was as follows:

Rental of machine	$0.144
Labor, coal, teams	0.140
Total per lin. ft.	$0.294

Work during 5 working days, trench 4 x 6 ft., total pipe laid, 1,944 ft., an average of 389 lin. ft. per working day, at a cost as follows:

Rental of machine	$0.130
Labor, coal, teams	.082
Total per lin. ft.	$0.212

Work by hand on same job, trench 5 ft. 10 in. by 4 ft. 4 in., cost of excavation and backfill, $0.826 per lin. ft. Laying and calking cost $0.143, and lead cost $0.285 per lin. ft.

Work of an Austin Trench Excavator. This excavator equipped with caterpillar traction, was used to excavate a portion of the trenches for underground telephone trunk lines between Washington and Philadelphia. According to *Engineering News*, May 25, 1911, the machine excavated daily 1,000 lin. ft. of trench 1.5 ft. wide and 3 ft. deep. The capacity of the machine was found to be about 3 ft. of clean trench for each minute of working time.

Again in *Engineering News*, Aug. 6, 1914, data are given on an Austin Trench Excavator which was used to excavate a water-pipe trench, 6 ft. wide by 6 ft. deep, through various kinds of materials, mostly gravel. In the actual operating time of 122 hr., 5,035 ft. of trench was excavated. The operating cost of the machine was about $15 per day.

Excavation in Chicago is described in *Engineering and Contracting*, July 17, 1912, as follows: An Austin No. 1 trench excavator equipped with buckets cutting 42 in. wide, was used in 1912 to excavate black loam and underlying blue and yellow clay. The average depth was 14 ft. Sheeting was composed of vertical planks set 2 ft. apart. The sewer was a 36-in. circular brick sewer, and it was necessary for three men to pick and undercut

the sides and trough the bottom after the machine. The daily cost of operating the excavator was as follows:

Engineman	$ 5.00
Fireman	2.50
Coal, ¾ to 1 ton	4.00
Oil and waste	0.50
Total per day	$12.00

The speed of the machine was regulated by the rate of bricklaying, the force employed on that part of the work being 30 men. From June 3 to July 8, 1,600 ft. was excavated but the machine had made runs on two favorable days of 184 ft. and 170 ft.

Cost with Trench Excavators at Alton, Ill. J. E. Schwab in *Engineering and Contracting*, Feb. 10, 1915, gives the following:

In the construction of this sewerage system there were used one small 00 Austin gasoline ditching machine which excavated a ditch 24 in. wide. The following output data were furnished by G. M. Johnson, of the Lillie Construction Co., sub-contractors, and owners of this machine:

Total amount of work done, lin. ft.	19,800
No. of working days	90
Average cut per day, lin. ft.	220
Maximum cut per day, lin. ft.	800
Average cost per day for operation	$30
Average Cost Per Foot for Laying Pipe.	Ct.
Operation of machine	13.6
Incidentals	1.4
Total cost per foot for excavation	15.0
Laying pipe	4.0
Refilling	3.0
Excavating, laying pipe, and refilling trench	22.0
Cost of cu. yd. of excavation	18.4

Depth of trench averaged 11 ft., with a maximum of 22 ft. and a minimum of 4 ft.

There was also used a Parsons steam ditching machine with backfiller, which excavated a ditch 28 in. wide. The following figures as to the work done by this machine are only approximate:

Total amount of work done, lin. ft.	18,000
Number of working days	90
Average cut per day, lin. ft.	200
Average cost per day for operation, laying pipe, and backfilling	$45
Average depth of trench excavated, ft.	11½

The balance of the main line sewer, where conditions were unfavorable for the use of excavating machines, and all laterals were put in by hand gangs.

The Buckeye Traction Ditcher. This excavator consists of a traveling engine equipped with a vertical digging wheel at the rear. This wheel is fitted with digging buckets of any of three types: The gumbo or open bucket for sticky soils; the solid or closed bucket for dry soils; and the combination contractors' bucket with cutting teeth for general hard work. To insure a clean ditch a shoe or runner, carrying the weight of the wheel, is drawn back of the cutters. The machine reaches the full depth at one cut and leaves the bottom at grade. It may be fitted with wheels or with caterpillar traction. Most of the machines are furnished with gasoline engines but the larger machines may be obtained with steam power.

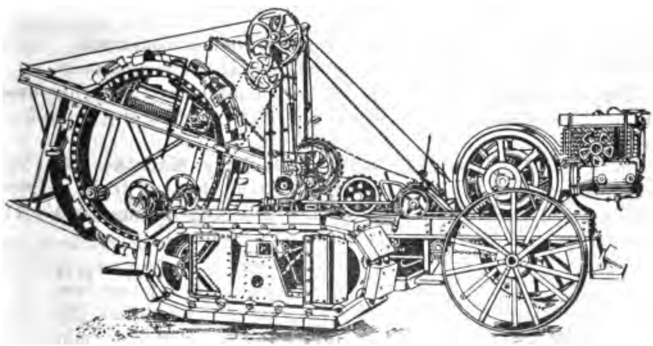


Fig. 23. Buckeye Traction Ditcher, 14½-in. x 4½-ft. Machine with Apron Traction.

These machines range in size from the No. 0, cutting 11.5 in. wide and 4.5 ft. deep, and the No. 1, cutting 11.5 and 14.5 in. wide and 4.5 ft. deep, to the No. 10 machine, cutting 28 and 36 in. wide and 12 ft. deep. They weigh from 7 to 38 tons and cost from about $240 to $280 per ton in 1916. Caterpillar wheels cost about $30 per ton of weight of the entire machine, extra. The caterpillar traction machine with wheel raised is shown in Fig. 23.

These machines are made by the Buckeye Traction Ditcher Co., Findlay, Ohio.

Cost with a Buckeye Traction Ditcher. *Engineering and Contracting*, Feb. 12, 1908, gives the following:

Thirty-six miles of trenching was excavated for a wooden pipe line for the water system at Greeley, Colo. About 2,000 ft. in rock was excavated by hand, and the remainder in earth by a

Buckeye 28-in. x 7.5-ft., 17-ton, drainage machine. Eight miles of trench was through gravel containing many stones, with some cemented gravel. The remainder was in clay, rather hard. The average number of linear feet per day was 627, or 222 cu. yd. In 10 hr. the machine dug from 600 to 1,000 lin. ft. in gravel, and up to 2,500 ft. in clay, while actually working, the trench being 30 in. wide and 4 ft. deep.

The daily cost of the work was as follows:

Engineman	$ 5
3 helpers at $3	9
Coal, 1 ton at $5	5
Plant charges	6
Total per day	$25

About 1 gal. of water per pound of coal is consumed.

The "plant charges" are estimated at 30% annually on a $5,200 excavator, and 250 days worked annually. On this basis the cost of 300 days' work averaged 4 ct. per lin. ft., or 10.7 ct. per cu. yd.

Costs of Tile Draining with a Buckeye Machine. At New London, O., a 14.5-in. x 4.5-ft. machine was used to drain a 1,000-acre farm. Twelve miles of ditches were dug during 1910. The cost of operation per 100 lin. ft. was as follows:

Man to run machine	$0.18
Man to lay tile	0.24
Fuel: gasoline at 13 ct. per gal.	0.11
Repairs: parts and labor	0.14
Oil and grease	0.01
Total per 100 lin. ft.	$0.68

The ditches averaged 2.5 ft. in depth. The soil was clayey and during the dry season was hard digging, and in wet weather very sticky. The apron wheels enabled the machine to be successfully operated in swamps that could not be crossed by teams. Ditches dug by hand the previous season cost $2.40 ct. per 100 lin. ft. Excluding the wages of the men laying tile, the cost was 44 ct. per 100 lin. ft., or less than 4 ct. per cu. yd., exclusive of interest and depreciation.

Cost of Tile Trenching with a Machine. A machine made by the Buckeye Traction Ditcher Co., of Findlay, Ohio, was used on the Northwest Experiment Farm, University of Minnesota, in 1903. The machine dug a trench 14½ in. wide and 4½ ft. deep. It had an 8-hp. boiler and consumed 450 lb. of coal and 4 bbl. of water per day. It dug 34,000 lin. ft. of trench in 45 days' actual working time, or 744 lin. ft. per day. The men who handled the machine were inexperienced.

The following was the cost:

	Per 100 ft.
Labor running machine	$0.45
Coal at $7.50 per ton	0.19
Water	0.13
Oil	0.01
Repairs	0.13
Total ditching	$0.91
Laying tile	0.18
Blinding	0.05
Incidentals	0.09
Totals	$1.23

The price of the machine was $1,400.

Although the machine was not well handled and had not at that time (1903) been perfected, it made a very creditable record of cost, as contrasted with hand work, for the latter cost $3.88 per 100 lin. ft. on the same farm.

Two men operated the machine.

I recently saw a machine of the same make and size on a farm in New Jersey where it was averaging 2,000 lin. ft. of trench (15 in. x 3 ft.) in 10 hr.

Tile Trenching with a Buckeye Ditcher. The following is from an abstract of Bulletin 110 of the University of Minnesota by *Engineering and Contracting*, Oct. 21, 1908.

A Buckeye Traction Ditcher, which cut a trench 4½ ft. deep and 14½ in. wide, had been sent to the farm in 1903 for demonstration purposes, and was used throughout the season. This machine consists of a four-wheel truck, 4 ft. wide and 12 ft. long. The distance between the wheel centers is 6 ft. 4 in., and 7 ft. between front and real axle. The rear axle serves as a drive shaft and is geared to the engine shaft by chain belting. On the front end of the truck is placed an 8-hp. vertical boiler, and immediately back of the boiler is a 6-hp. single engine. Attached to the rear of the truck is a frame carrying the cutting wheel.

This machine, in 63 days of which 45 were working days, dug 33,498 lin. ft. of trench, an average of 744 ft. per working day. The machine was operated at its lowest working speed, which would cut 100 ft. of trench in 32 min., but unavoidable delays cut down the daily run. At wet spots planking was required beneath the traction wheels, and trouble at the places caused much delay. The earth collected on the elevator rollers, and the grass roots sticking on the knives made it necessary to clean them after every 35 or 40 ft. This latter trouble was partially remedied by turning two furrows with a breaking plow along the side lines of the proposed trench. Another difficulty was

caused in wet soil by the shoe rolling up the soil from the bottom of the trench, and necessitating hand dressing with a scoop. The machine as a rule required the services of two men, one to attend the boiler and engine and another to look after the ratchet wheels that control the line and grade. The coal consumption averaged 60 lb. per 100 ft. of trench, varying from 50 to 80 lb. according as the weather was cold or warm and varying with the nature of the soil. This coal was carried in the water tank and its conveyance to the work is charged to water account. About 9 bbls. of water were carried per tank load. This water was placed in barrels along the trench, one barrel per 200 ft. being required.

The speed of the machine in moving from one job to another, including the time lost while taking on coal and water, was about ¾ mile per hr.

As the machine could not make curves of shorter radius than 300 ft. it was necessary to start most of the ditches with hand work.

Table I gives the cost of three examples of trenching with the machine. Example 1 is the cost of digging 8,750 lin. ft. of trench in 13 working days. In this time the machine was laid up three days for repairs, the actual time worked being 10 days. The average run was 875 ft. per day. This example represents average conditions and shows what the machine can do in average soil.

TABLE I — COST OF TRENCHING AND TILLING 100 FT.

	Example 1	Example 2	Example 3
Labor of running machine	$0.457	$0.409	$0.516
Coal	0.188	0.190	0.263
Water	0.126	0.087	0.126
Oil	0.012	0.010	0.014
Repairs	0.112	0.100	0.200
Laying tile	0.183	0.212	0.235
Blinding	0.048	0.053	0.062
Incidentals	0.092	0.015	0.012
Total per 100 ft.	$1.218	$1.076	$1.428

Coal cost $7.50 per ton delivered at the farm.

Example 2 represents more favorable conditions. The soil was dry, the sod thin, and the work was closer to headquarters, requiring less time for the men in going and coming back and forth. There were 400 ft. of trench at the outlet ends of two ditches that exceeded 4.5 ft. in depth. These sections were dug by hand. On five other ditches there were from 100 to 200 ft. at the outlets that exceeded 4.5 ft. in depth, and over these the machine excavated to its full working depth, the bottom of the trenches being dug to grade by hand. This extra cost of hand work is

not shown separately but is added to the machine account. The total length dug in this section was 10,450 ft.

Example 3 gives the cost of 14,298 ft. dug in wet soil covered with broken sod. Two ditches were in wild sod that had never been broken.

The average cost of trenching, tile laying, and blinding for all machine work was $1.25 per 100 ft. This compares very favorably with the cost of digging 100 ft. of the same sized trench by hand, which cost was $3.88 per 100 ft.

The machine did not work as rapidly as was expected, and there were more delays from breaks than looked for. However, the soil is difficult to work, being much slower to handle by either spade or scraper than in many localities where tile work is done, and many of the delays were due to the nature of the soil, although the work was performed at the favorable season of the year. The best condition for machine work would be in dry ground which is in cultivation, the drier and harder the soil, the speedier can the trenching be done.

The machines which have been made during the past season have a number of improvements over the one used. It is believed that many of the difficulties with this machine would not be experienced in one of the later models.

On account of the scarcity and high price of labor, the tiling system could not have been completed this season if the machine had not been used, and the cost of work done would have been much greater. The machine was operated and all the work in connection with it was done entirely by farm help. The foreman operated the machine the greater part of the time. When the machine was laid up for repairs, the help was used on other farm work, the rules for a day's work on the farm being that the men should leave the barn at 7 and 1 o'clock and arrive at the barn at 12 and 6 o'clock. In the foregoing table of cost per 100 ft., no allowance was made for the first cost of machine. This machine, if bought new, would cost $1,400. As it was a machine which had been used by the factory for demonstration purposes, it was considered as a second-hand machine and was secured by the state at much less than the original cost. An estimate of the depreciation of machinery or interest on the investment is not considered in the cost of the work.

The Havland Tile Ditcher. This machine, Fig. 24, is designed for ditching and tiling wet farm lands. The outfit consists of a tractor that draws a ditcher or excavator, and is made in two sizes known as the single wheel which has a single digging chain and the double wheel which has a double digging chain. Both machines have caterpillar traction. Four-fifths of the weight is 25

to 40 ft. ahead of the ditch bottom. Tile can be laid accurately to grade. The diggers or shovels are fastened to a chain belt, and are so arranged that when the shovel strikes a stone or other unyielding obstruction the chain buckles and allows the shovel to travel over the obstruction. Shovels are made as wide as 42 in., and each shovel and reamer is automatically cleaned. The reamer regulates the width of excavation. The earth is thrown to one side by belt conveyors. Behind the digger in the ditch is drawn a sheeting form which prevents the bank from caving until the tile has been laid. Tile up to 12-in. diameter is laid automatically through a spout; tile 14 to 30-in. diameter is laid by hand. The dimensions of the machines are as follows:

	Single wheel	Double wheel
Length of tractor, ft.	22	22
Width of tractor, ft.	10	10
Length of ditcher, ft.	26	26
Width of ditcher, ft.	10	10
Shipping weight, lb.	34,000	44,000
Engine horse power	45	45
Price	$4,500	$6,000
Tile, diam. lin. ft. deep	10 to 20	14 to 30
Capacity, 10 to 12 ft. deep. ft. per hr.	30 to 50	25 to 40
Capacity, 6 to 8 ft. deep, ft. per hr...	60 to 100	40 to 60
Capacity, 3 to 6 ft. deep, ft. per hr...	100 to 150	75 to 100
Road speed, miles per hr.	1	1

Fig. 24. Havland Tile Ditcher.

The crew required consists of 4 to 6 men of whom one is foreman and one engineman. With a single wheel machine and four men 1,200 ft. of 8-in. tile has been laid 6 ft. deep in one day. At the same place six men laid 150 ft. by hand to the same depth. The labor cost by hand was $12.60 per day. The labor, gasoline and oil for the machine cost $10.50 per day. It is claimed that tile can be laid by these machines under conditions such that it is impossible to lay by hand.

This machine is made by the St. Paul Mfg. Co., St. Paul, Minn.

Use of a Trenching Excavator on Marsh Land. In *Engineering and Contracting*, Oct. 30, 1912, the methods and cost of constructing a 48-in. wood stave pipe line across marsh land in Atlantic City, N. J., is given. A Parsons Trenching machine excavated 2.5 ft. deep and 6 ft. wide in a trench filled with water, at a rate of 500 ft. per day. The machine was carried on 4 x 12-in. planks, 12 ft. long, laid cross-ways of the trench, with 4 x 6-in. plank, 20 ft. long, laid on the top for the traction wheels to rest on. This work cost 20 ct. per ft., coal cost $5 per ton and was carried to the machine across the marsh by hand in 50-lb. sacks. Water was rolled in barrels across the marsh ½ mile to the machine.

Trenching by hand, cutting a ditch 8 ft. wide, trimming bottom and sides, the men in the ditch standing on a movable platform dragged along with them, cost 9 ct. per cu. yd. All spoil was thrown to one side. Backfilling the pipe cost 9 ct. per ft. Pumping cost 10 ct. per ft.

The cost of constructing an embankment 18 in. thick on top and 2 ft. wide on the sides over the pipe, to a width of 6 ft. at the top and 12 ft. at the meadow level, all the material being taken from the meadow, 16 ft. from the center of the pipe, cost 23.1 ct. per ft. The trench had to be cut even and graded to act as a drain for the water in the pipe trench. The daily cost of the embankment was as follows:

1 foreman	$ 4.00
1 sub-foreman	2.50
15 laborers at $1.75	26.25
1 waterboy	1.00
Cost of sharpening tools	1.00
Total, 150 ft. per day	$34.75

Excavation foremen received $3.50 per 10-hr. day, pump men, $3.50, and watchmen, $2.00.

Trench Excavation by Hydraulicking. In *Engineering Record*, Nov. 8, 1913, Joseph Jenson gives the following:

Excavation for the puddle core-wall trench for the Sevier River Dam of the Otter Creek Reservoir, Utah, was started by a contractor with teams and scrapers. The trench was specified to be not more than 25 ft. in width at top and 15 ft. at bed rock, and a depth of about 30 ft. The material was a mixture varying from silt and quicksand to gravel, boulders, and very large rock fragments. No timbering was used and the trench caved until it was 40 ft. wide at the top, and the rate of caving in and sliding down was equivalent to the rate of excavating the material. The contractor was relieved from further operations in August, 1910, a year after signing the contract.

Work was then resumed by the State. Vertical sheeting, driven in 4.5 ft. stages and braced horizontally at the top of each stage, was used. The closeness of the braces (4.5 ft. each way) prevented the use of plows, scrapers, or cars at the bottom of the trench. It was therefore decided to loosen the material with a water jet, and to wash it along the bottom of the trench to a point where the fine materials could be drawn up by a pump, the coarse materials being handled by dump boxes and derricks.

The plant consisted of 12,200 ft. of 16-in. wood stave pipe-line placed underground, a small electric-power plant with house, transmission lines, motor and pump settings. Water was obtained at an elevation of 430 ft. Above the power house a 75-kw. dynamo, operated by a Pelton wheel, furnished power for a 75-hp. motor driving a 12-in. Gould pump. A 4-in. wrought-iron pipe from the main pipe ran along the trench bank and fed two hose-lines at the ends of which were fire-nozzles. The pressure of the water jet at the nozzles was 180 to 200 lb. per sq. in. The pumping and hoisting plant cost $7,322, which does not include the cost of the power pipe line which was charged to the construction of the hydraulic filling of the dam.

In operation it was necessary to furnish additional water to the trench in order to keep the 12-in. pump supplied. The material was loosened and washed by the nozzlemen, the fine materials being forced to the pump and the coarser being left in piles along the trench. These latter were loaded by shovels and forks into dump boxes and hoisted by a derrick operated by teams on a whip cable.

The cost of excavating 8,000 cu. yd. was $2.90 per cu. yd. to which must be added the first cost of the plant less its salvage value, $4,322, making a total of $3.43 per cu. yd.

Methods of Sheeting and Bracing. The following is from an article in *Engineering and Contracting*, Aug. 4, 1909. Trenches of slight depth, 3 to 4 ft., even in sandy soil do not, as a rule, require bracing. Saturating the soil with water will often enable sand banks to stand up for some little time. Trenches over 4 ft. in depth usually require bracing. The change of moisture condition of the exposed soil, as well as the load imposed by the excavated material and passing laborers, is apt to cause a trench to cave, no matter how solid it looks when first excavated.

The simplest form of bracing, suitable for trenches of from 4 to 7 ft. in depth, consists of a board placed horizontally along each wall of the trench. These boards are held against the trench banks by braces wedged between them. Deeper trenches require more elaborate protection. The entire wall of the trench must be protected either by sheeting set in place as soon as the excavation

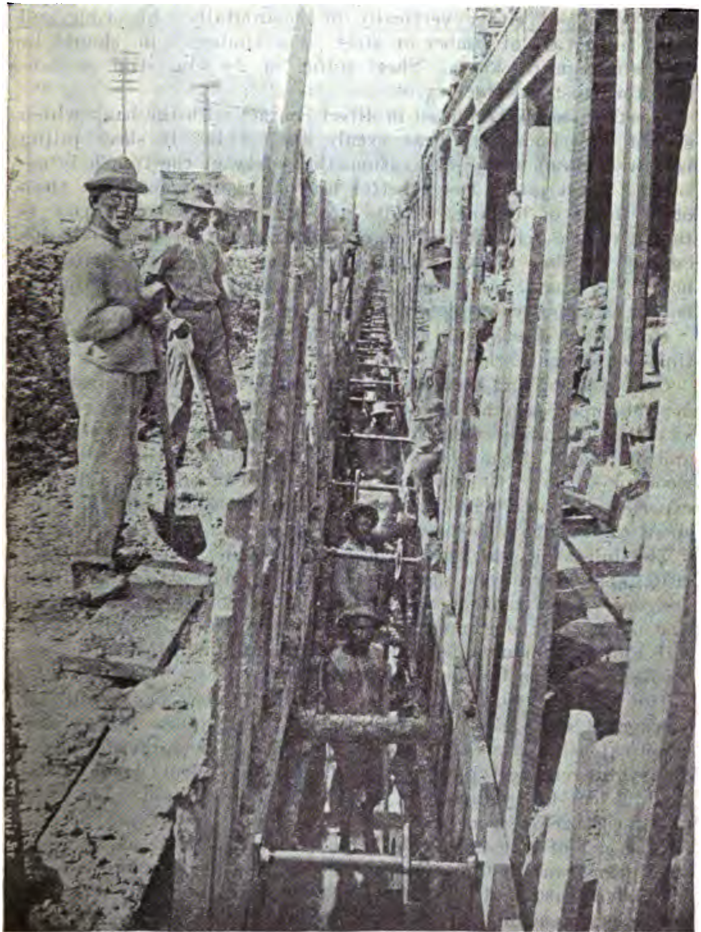


Fig. 25. Vertical Sheeting and Extensible Braces.

is completed, or by sheet piling which is driven ahead of the excavation. Sheet piling is always driven vertically, but sheeting may be placed either vertically or horizontally. Sheeting and sheet piling are of timber or steel. For timber, 2 in. should be the minimum thickness. Sheet piling of 2 x 8-in. stuff is usually the most satisfactory.

Sheeting should be placed in direct contact with the bank which should be trimmed to bear evenly against it. If sheet piling is driven ahead of the excavation, the safety of the trench is assured. Sheet piling has a better bearing against the bank than other forms of bracing, but its greatest point of superiority is that it can be driven below the depth of excavation where it helps cut off the flow of water and where the unexcavated material, holding it apart, takes the place of bracing. This gives the laborers an unobstructed place to work in.

Horizontal sheeting is not recommended except under obstructions which make the use of vertical bracing impossible.

Cost of Wood and Steel Sheeting. The cost of sheeting tranches depends upon several factors: (1) The nature of the ground; (2) the size of the trench; (3) the methods pursued in driving and pulling; (4) the kind of material used for sheeting (whether wood or steel); (5) the type of braces used; (6) the difficulty experienced in driving; (7) the skill of the workmen; and (8) the speed with which the excavation proceeds.

The following was published in *Engineering Record,* May 23, 1915. The work was the construction of narrow sewer, drain and water pipe trenches, 8 to 15 ft. deep, in soil of glacial origin. The nature of the ground varied from very sandy to fairly firm soil, and the amount of sheeting and bracing required varied accordingly. Some bracing was used at all times.

The sheeting used was either 2 x 8-in. lumber or Wemlinger corrugated steel piling, and the bracing was 3 x 9-in. lumber and Dunn extensible braces. At the beginning of the work, 400 pieces of Wemlinger steel piling, 10 ft. long, and about 5,000 ft. of 2 x 9-in. long-leaf yellow pine planking were purchased. The steel piling cost 28 ct. per sq. ft. and the lumber about $35 per M. At the end of one season the lumber had been used up, but the steel piling was in first class shape and was used during several successive seasons although subjected to hard usage for purposes other than trenching.

In trenches averaging 9 ft. deep 3 men averaged 70 ft. of trench sheeted solid with wood per 10-hr. day. In firm sand the average was 100 ft., but in caving sand it was 30 ft. a day. The same gang removed the sheeting at the rate of 210 ft. of trench per

Fig. 26. Horizontal Sheeting and Extensible Trench Braces.

day. When the sheeting was not solid, but spaced 3 to 6 ft. apart, 3 men averaged 150 ft. of trench braced per day.

Using steel sheeting 3 men averaged 60 ft. of trench (11 ft. deep) sheeted per day. In pulling this sheeting with a differential block, 2 men averaged 45 ft. of trench per day, the trench being filled to a depth of 6 ft. before pulling.

In some work in Peoria, Ill., the engineer for the contractors kept close account and found that in trenches from 8 to 16 ft. deep in sand with 2 x 8 sheeting and 6 x 6 braces of hemlock, the sheeting cost in place and pulled after use, ready to use again, from 10 to 25 ct. per lin. ft. of trench. The excavating and back filling, including contractors' profit, cost from 21 ct. per ft. for trench less than 8 ft. deep to 76 ct. for trench 14 to 16 ft. deep.

Cost of Driving Sheet Piles. In *Municipal Engineering*, Vol. xxi, p. 409, 1901, Emmett Steece says that the cost of driving sheet piles is subject to greater variation than round piles in soft soil and will vary from 5 to 12.5 ct. in trenches less than 10 ft. and from 25 to 75 ct. per ft. in trenches between 10 and 20 ft. in depth for pipe sewers, and increasing slightly with the size of pipe. For larger trenches the cost increases rapidly with the width and depth. A trench 25 ft. deep and 16 ft. wide costs about $2.75 per ft. to sheeting for driving and removing.

The Cost of Driving by Pile Driver. Victor Windett gives the following in *Engineering and Contracting*, June 14, 1911.

In alluvial soil 2 x 12 in., 14 ft. and 3 x 12 in., 24 ft. sheeting was driven by a 2,000-lb. drop-hammer pile-driver. No difficulty was experienced in sheeting 150 ft. of trench per day. The lumber was delivered along the line of the trench by teams. The pile-driver crew consisted of 9 men.

The cost of preparation of plain ordinary trench sheeting is as follows:

467 pieces, 2 x 8 in., 12 ft. and 14 ft. trench sheeting, totaled 10,900 ft. B.M., and the labor cost of pointing and trimming the top was $2.60 per 1,000 ft. B.M., or 6 ct. per pile, labor being 27 ct. per hr.

For steam-shovel work, as at Hegewisch in sand a light pile-driver was used with two hammers of 1,200 lb. each (see Fig. 27). The sheeting used was triple lap. The center piece was 2 x 10 in. x 4 ft., with two 1 x 4-in. x 12-ft. side pieces, made up for a 2-in. tongue and groove. In a 9-hr. day 240 pieces of sheeting could be driven easily by the crew of 9 men, at a labor cost of 10 ct. per piece.

The sheeting was pulled after the trench was partly backfilled, by a double drum, double cylinder engine on a platform some-

what similar to the pile-driver but substituting a hinged frame for the leads. A $\frac{1}{2}$-in. chain and $\frac{5}{8}$-in. cable were used for the lines. There were two lines, one for each side of the trench. This machine would pull sheeting for 100 ft. of trench in 2 hr. The crew consisted of an engineman, winchman, hooker-on and sheeting-catcher to land the sheeting on the bank within reach of a team.

The wear and tear on the sheeting was very small, as far as

Fig. 27. Sheet Pile-Driver with Double Leads for Trench Work

the 2 x 10-in. pieces were concerned. They were used nine times and then made into bottoms for catch basins. The 1 x 4-in. strips required quite frequent renewal. Possibly it might have been cheaper to use 2-in. lumber instead. This sheeting was triple lap, middle piece, 2 by 12 in., 14 ft. long. Side pieces, 1 by 4 in., 10 ft. long. 732 pieces (34.5 ft. B. M. each). Labor making up (including pointing and heading to top width of 8 in.) at 31 ct. per hr., cost 9.3 ct. per piece or $2.60 per 1,000 ft. B. M.

The stringers used were generally 3 x 12 in. or 4 x 12 in. and 16 ft. in length of long leaf yellow pine.

Braces were generally 6 x 6-in. yellow pine. In Gary, Ind., where the country was covered by a growth of various oaks, mainly small trees, many braces were cut from the standing timber. These braces were usually 3 to 5 in. in diameter. Dunn trench screws are highly advantageous on account of ease of placing and removing the braces and of keeping them tight.

Steel Sheeting at Watertown, N. Y. *Engineering and Contracting*, Nov. 15, 1911, gives the following:

Wemlinger corrugated steel piling was used for sheeting sewer pipe trenches at Watertown, N. Y. The average cut was 15 ft. The soil was sand to a depth of 10 ft., and a wet sand and gravel beneath that point. Four hundred sheets of 1/8-in. piling, each 1 ft. wide by 10 ft. long, were used. A 650-lb. steam hammer, furnished with power from a road roller, drove the piling. The trench was first excavated to a depth of 5 ft. Three men then placed the piling upright at each side of the trench, the rate of placing being 32 sheets in 1.5 hr. These sheets were then driven to grade by the hammer hung from an A-frame, at the rate of 1 sheet driven 5 ft. in 35 sec. Including the time required for moving the hammer and A-frame, the rate of driving was 7 ft. of trench sheeted per hour. Spruce rangers, 4 x 6 in. x 16 ft. long were used. Braces were placed 7 ft. apart.

Removing Sheeting. In pulling sheeting and sheet piles, various methods are used. The lower waling pieces are taken out as the trench is backfilled. Then after 50% or more of the backfilling is done the sheeting boards are drawn, although in some exceptional cases the sheeting is left in place. Chains, clamps

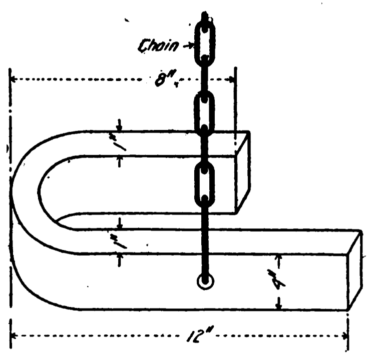


Fig. 28. Device for Pulling Sheet Piles.

and grabs of various kinds, are used to pull the boards. Derricks and cableways are used as the power to pull them, although they are often pulled by hand. Fig. 28 shows a small tool used for pulling sheet piles. It can be used with a lever, operated by men, with a derrick or a cableway. It fits around the pile and as the pull is made it clamps itself to the board so that it seldom slips. If more than one pull is needed to take out the pile, the tool releases itself as soon as the pull is stopped and it slides down the board, taking a new hold the instant power is on it. Besides being simple in operation, this tool does not injure the boards, as do chains, clamps and grabs.

A Machine for Pulling Sheet Piling. *Engineering and Contracting*, Dec. 6, 1911, gives the following:

This pile puller, Fig. 29, is the invention of R. J. Blackburn and was used on the Glaise Creek sewer, Louisville, Ky. The top of the fall line of the derrick was attached to the top of the tripod while the closing line passed around the special blocks as shown. With this rig an average of 30 twenty-foot steel piles were pulled per hour. The labor force required consisted of three men and the derrick crew.

In the construction of some sewers in St. Louis, Missouri, steel sheet piling was driven to a depth of 40 ft. and, after excavating nearly to quicksand, bulkheads of plank piling were built across the trench about every 20 ft. These bulkheads were 24 ft. high and were composed of timbers 8 in. thick. When the completed masonry of the sewer neared one of these bulkheads it was not feasible to pull the plank piling until the fill had been at least partly completed. The heavy cross timbers, in addition, were partly braced by the piling and had to be left in order to support the steel piling in the sides.

Cutting off Piling with Pneumatic Augers. The following method is given in *Engineering News*, Aug. 6, 1914. The first attempt to cut off the piling was with an axe, but this method was found to be extremely unsatisfactory. Large wood chisels fitted to pneumatic hammers were next tried without satisfactory results. A 1¼-in. wood boring auger operated by a "Little David" compressed air motor was tried, and found to be a practical means for cutting these thick planks. About seven 1¼-in. holes were required to sever a pile, and the time consumed in boring each of the holes 8 in. long was from 20 to 25 sec. The entire time consumed in making two cuts across the trench was between 1.5 and 2 hr.

Driving Wakefield Sheet Piling. The following is given in *Engineering News*, May 28, 1903. The construction of intercepting sewers for the purpose of diverting sewage into the

Chicago Drainage Canal was undertaken in 1901 by the city, employing day labor, and having all work done under the supervision of its own engineers.

The following relates to work done on Section G, which ex-

Fig. 29. Blackburn Pile Puller. Closing Line Pulling Up a 20-Ft. Pile.

tended from 39th to 51st streets, and on Section H, between 51st and 63d streets. As this was the city's first experience in construction work on a large scale, it was necessary to secure an entirely new plant. Accordingly, the city built, with its own labor, a turntable drop-hammer pile driver, for use on Section

G. The driver had a hammer weighing 3,000 lb., and was equipped with a 7 x 10-in. double-drum hoisting engine and a duplex steam pump for jetting. The machine cost $2,200.

As the sewer for a distance of about 2,500 ft. would be under the shoal water of the lake, and for the rest of the distance very close to the water's edge, it was necessary to use sheeting, which would be practically water tight. Accordingly, Wakefield sheet piling was used, the lumber employed in its construction being 2 x 12-in. x 12-ft., Norway and Georgia pine, surfaced one side and one edge. For most of the work Southern pine was used. In practice, however, it was found that Norway pine would stand 50% more blows under a drop hammer; and, in consequence, Norway sheet piling was used where there was difficult driving.

About 12 ft. below city stratum the clay line was found. Immediately above this was a layer of fine blue sand mixed with shot clay. This stratum when loose and wet acts very much like quicksand. Above this stratum was ordinary lake sand. The sand was very solid and compact, owing to the action of the waves of the lake. But with the exception of gravel spots the seepage was small, considering the nearness to the lake. The first sheeting was driven nearly to the bottom of the proposed excavation; but later it was found that sheeting driven 4 to 5 ft. into the clay would do sufficiently well. In order to have the sheeting left to a sufficient height above the line of the lake for protection against high water, 20 ft. of material was used with some exceptions.

In the bracing, 10 x 12-in. x 22-ft. stringers and 10 x 10-in. x 20-ft. braces were used. Three sets of stringers and braces were found sufficient for most of the distance. In some places it was necessary, on account of bad ground and swelling clay, to reinforce both stringers and braces. Throughout the entire work, 2-in. Dunn screw-braces were used.

In construction, the top set of stringers and braces followed the scraping and leveling. The distance between the sheeting was 22 ft. for the 16-ft. conduit and 21¼ ft. for the 15¼-ft. conduit. A clearance of about 9 in. between the sheeting and sewer brickwork was allowed.

In the operation it was found practical to swing the pile driving apparatus about once every day. Ordinarily about 50 ft. of sheeting in each direction was driven on one side, and then 50 ft. in each direction on the other side. A water jet for jetting the clay was used with marked success. Ordinarily, after jetting to the clay and getting the piling into position, four or five blows of the hammer were sufficient. In many cases isolated rocks, about 1½ ft. in their largest dimensions, were found from 2 to

8 ft. below the surface. These were disposed of by jetting a large hole beside them. The piles were held in place during driving by a ⅝-in. buck line, attached to the front drum of the hoisting engine, and leading through the sheaves attached to the pile driver and sheeting in place, to and around the pile to be driven.

In making each Wakefield pile, 50-penny wire spikes were used. Half-inch carriage bolts were tried as fastings, but it was found that the carpenters could make at least twice the number of sheet piles when 50-penny wire spikes were used. Eight to ten spikes were used per pile. The pile-driving crew followed the gang setting the top braces. On straight work at least it was planned to have a distance of about 400 ft. between the pile driver and the excavating derrick, because when the driving was too near there was trouble with seepage water from the jet.

In ordinary driving, the crew averaged about 90 pieces of sheeting per 8 hr. This is equivalent to 45 ft. of trench sheet piled. The largest day's work was 120 pieces of sheeting placed. On some days, however, when such obstructions as piers were encountered, not more than 12 pieces of sheeting were driven; this occurred once perhaps in 300 to 400 ft.

The pile driving crew consisted of the following:

	Per day
1 foreman	$ 4.16
1 engineman	4.80
1 fireman	2.50
2 carpenters at $3.60	7.20
4 laborers at $2.50	10.00
1 jet man	3.00
1 ladder man	3.00
2 wench men at $3.00	6.00
Total labor cost per day	$40.66

As about 45 ft. of trench was sheetpiled per 8 hr., the labor cost per linear foot of sewer amounted to 90 ct. The labor cost per pile was 45 ct. The bill of materials required for 90 ft. of piling (the avearage amount placed in an 8-hr. day) was as follows:

10.8 M. ft. B. M. 2 x 12-in. x 20 ft, timber at $22	$237.60
900 spikes, at $2.65 per 100 lb.	23 85
1 ton coal for pile driver	2.90
Total	$264.35

Adding the total labor cost of $40.66 and the total cost for material, etc., $264.35, we have $305 as the total cost of 90 ft. of piling, or 90 piles. From the above it will be seen that the cost per pile amounts to $3.38, of which $0.47 was for labor. The labor cost per 1,000 ft. B. M. of piling was about $3.90.

Another pile driver was built by the city for the construction of the sheet piling in that section of the intercepting sewer between

51st and 73d streets, known as Section H. This machine was also constructed on a turntable and could be swung from one side of the trench to the other. In order to secure a good foundation bearing for the runways and rollers the span of the lower bed was made 34 ft. The driver was equipped with a 7 x 10-in. double-drum engine, had 40-ft. leads and a 2,500-lb. hammer. A jet pump, with water tank, 20 ft. jet tube and other appliances were among the equipment.

As in the first case, the sheeting was of the ordinary Wakefield pattern, made up of 2 x 12-in. plank, fastened together, however, by 60-penny spikes. The method of driving this sheeting was as follows: The top set of stringers and braces were put in place for 100 ft. to 200 ft. in advance, and about 18 in. below the surface of the street; a second set of stringers, parallel with the street, made up of 4 x 12-in. plank, was put in about 5 in. outside of the main stringers and on the same level as those inside, for the purpose of keeping the sheeting in line. All braces and timbers were then covered with sand to prevent their being washed out by the water jet. The sheeting used was 18 ft., 20 ft., 22 ft. and 24 ft long, depending on the depth of the clay. The top of the sheeting was driven to about 1 ft. below the street grade, and the lower end was from 2 to 4 ft. in the clay. For each pile a hole was jetted to the clay line, and as soon as the jet tube was pulled out, a pile was dropped into place and pulled over the tongue of the previous pile. Excellent alignment was obtained by using a "buck line" to hold the sheeting in place while being driven. In this case the "buck line" consisted of an old cable having a loop at one end to go over the head of the pile, the other end of the cable, after passing through a couple of snatch blocks, being attached to the hoisting engine.

From 75 to 110 piles were driven in 8 hr., the number depending somewhat on the character of the ground; 85 piles, however, were considered a fair day's work.

The pile driving crew and wages were as follows per day:

1 foreman	$ 4.16
1 jet man	3.50
2 ladder men	5.00
2 wench men	6.00
1 pileman	2.75
1 engineman	4.80
1 fireman	2.75
4 laborers	10.00
2 carpenters	8.40
Total labor per day	$47.36

An average of 85 piles per day were driven, which is equivalent to about 42.5 ft. of trench piled. This was at the rate of $1.11 per ft. of trench for the labor cost. The labor cost per pile was 55

ct. The bill of material required for 85 ft. of piling was as follows:

10.2 M. ft., 2-in. x 12-in. x 20 ft. timber at $25	$255.00
850 spikes, at $2.65 per 100	22.52
1 ton coal for pile driver	2.90
Total materials	$280.42

From the above it will be seen that the total cost for material and driving was $3.85 for each pile, of which $0.55 was for labor. The labor cost for 1,000 ft. B. M. of piling was about $4.58.

Trench in Muck Soil. In excavating the foundation of the Manchester Ship Canal grain elevators, through very soft soil, great difficulty was encountered. This work is described by G. G. Lynde in the *Proceedings of the Institution of Civil Engineers*, vol. 137 (1898–99). The upper 14 to 18 ft. of the soil consisted of a black mud which had been deposited by previous dredging work. About this "sludge" red sand and small lumps of sandstone had been spread to a depth of 1.5 to 2.5 ft. The ground underlying the sludge consisted of an alluvial deposit, a bed of blue silt, 4 ft. thick, being found at a depth of 18 ft. below the upper ground surface covering a bed of wet running sand, 3 ft. thick, which lay on coarse sand and gravel. The black mud had naturally the consistency of butter, and in this state was as impervious to water as clay puddle, but when mixed and stirred with water, as in the bottom of the trenches, it became thin black mud.

As the entire excavation was made by steam traveling-cranes loading into cars hauled by locomotives, the weight of machinery caused a settlement of the ground in the immediate neighborhood and a corresponding rise in the bottoms of the trenches and elsewhere. A few of the trenches in fairly good ground were sunk by poling boards in the ordinary way, but in other trenches no progress could be made, the bottom rising as fast as it was excavated and the timbering and surrounding ground sinking at the same time.

Certain trenches 8.5 ft. wide and from 23 to 26.5 ft. deep were excavated by the following method. The sludge was 17 ft. deep with a somewhat hardened crust, and it was decided to use a sheeting plank or runner 2.5 in. thick by 7 in. wide, sharpened to a chisel point, and driven with the bevelled side towards the trench, so that the tendency of this sheeting plank was to incline outwards. The depth of the trench would have required long and unwieldy sheeting plank had they been driven from the surface to the full depth, so an excavation was first made in the hardened crust and sheeting 6 ft. long was first placed. Two frames were set, each consisting of 2 walings of 9 x 3-in. timber

12 ft. long, with 3 struts 8 in. square capped with 1-in. boards as shown in Fig. 30. Runners 14 ft. long were driven inside these walings into the solid ground by a small hand-operated weight of 300 lb., as shown in Fig. 30.

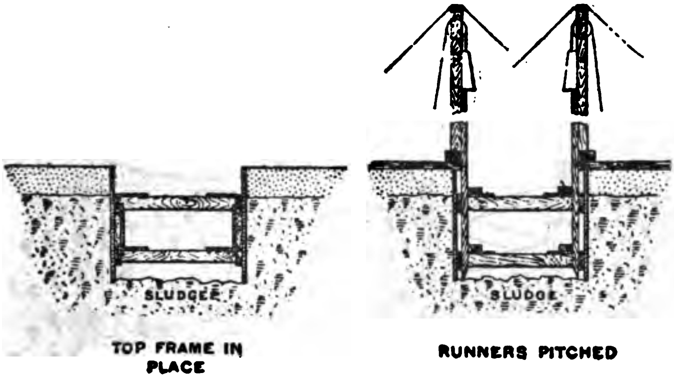


Fig. 30. Top Frame in Place and Runners Pitched.

The excavation was then carried down with frames of 3 x 9-in. walings and 8-in. struts inserted every 2 ft. deep, as shown in Fig. 31.

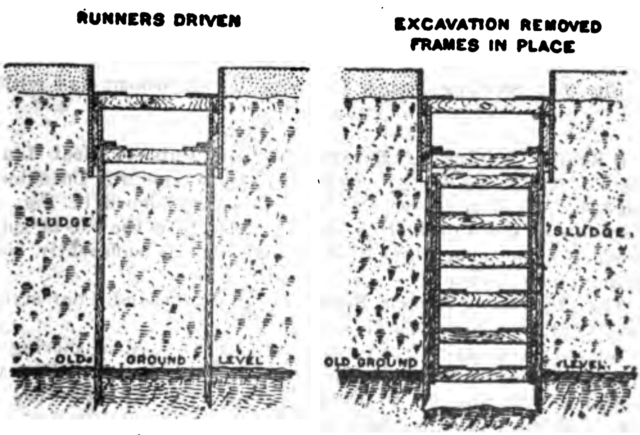
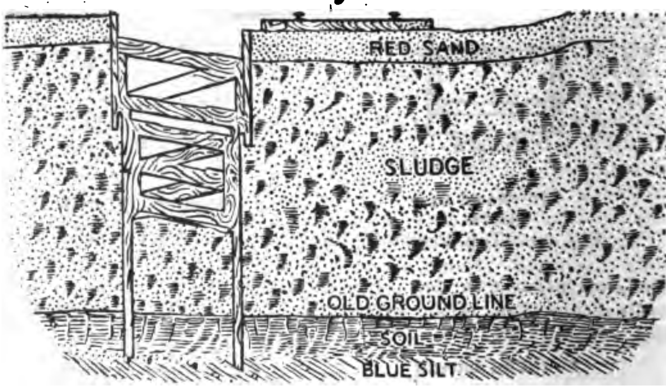


Fig. 31. Runners Driven, and Excavation Removed Frames in Place.

Curious effects were met with during the excavation of these trenches. The bottoms of the trenches were continually rising and a corresponding fall in the level of the surrounding ground took place. The ground sank as much as 3 ft. under the traffic of the locomotives and cars. Thus the boards on the loaded side of the trench sank while the timber on the inner side generally retained its position, endangering the whole structure. The struts or braces were thus transformed into diagonals, and to counteract this motion opposite diagonals were inserted, as shown in Fig. 32.

Fig. 9.



Scale, 1 inch = 12 feet.

Fig. 32. Showing Trench Distorted by Settlement and with Counter Rakers.

O'Rourke Method of Excavating Deep Cuts to Neat Lines. John F. O'Rourke has patented and used successfully on subway construction in Brooklyn, N. Y., the method shown in Fig. 33. *Engineering and Contracting*, June 7, 1916, gives the patent specifications. The general method of procedure is sufficiently clear without description.

The Bottomley Trench Brace. *Engineering and Contracting*, Dec. 11, 1912, gives the following:

An improved fitting for timber braces to be used in shoring up trenches in bad ground has just been put on the market by the Bottomley Machine Co. of Alliance, Ohio. Fig. 34 shows the fitting and the timber required in its utilization.

This fitting renders unnecessary the use of solid 4 x 4-in., 6 x 6-in., and 8 x 8-in. timbers for braces. In using it two pieces

of 2 x 4-in., 2 x 6-in., or 2 x 8-in. timbers are sawed the same length. The fitting is then fastened to the pieces selected by means of lag screws. The brace so formed is made rigid by spik-

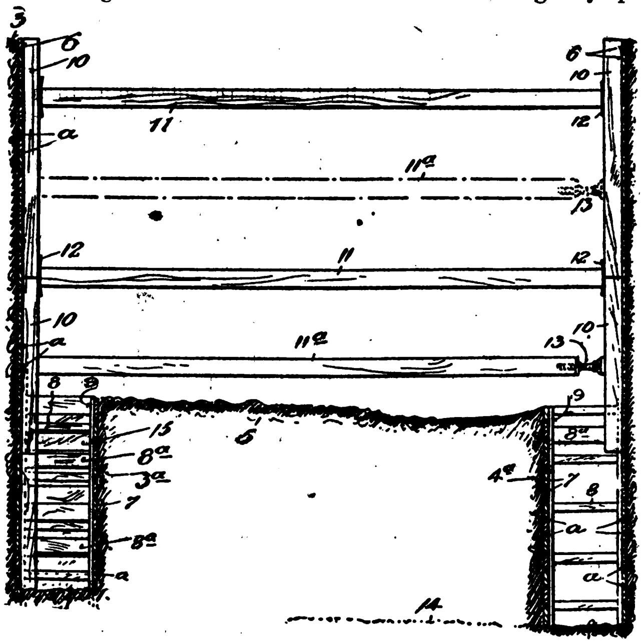


Fig. 33. Typical Section Showing Method of Excavating Deep Cuts with Vertical Sides.

ing two short pieces of the same scantling as the long pieces between the latter. The small block at the end adjacent to the casting may be set clear of the screw or hollowed out to box the screw

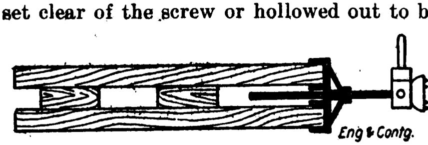


Fig. 34. The Bottomley Trench Brace and Built-Up Timber.

in. Similarly, if desired, instead of using the two small blocks the timber can be built in solid. In that case the screw is boxed in.

This device enables the contractor to utilize old but solid timber which has been used for other purposes on the work. This effects a considerable saving in cost of timber over buying solid stuff. Moreover the casting can be fitted to the 2-in. timber in much less time than that required to fit a cast head on a solid stick.

The casting is made of malleable iron threaded so as to engage the screw. The screw is 1½ in. in diameter and is threaded for a length of 14 in. The vice handle is 1 x 9 in. The lag screws required for fastening the casting to the timber are furnished with it.

The Kalamazoo Extensible Trench Brace, made by the Kalamazoo Foundry and Machine Co. of Kalamazoo, Mich., is shown in Fig. 35.

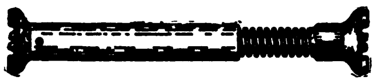


Fig. 35. Kalamazoo Extensible Trench Brace.

Methods and Costs of Trench Pumping. The cost of removing water from trenches is sometimes very high. Nevertheless, no matter how expensive the removal of water may be, it is usually less than the added cost of excavation and pipe construction in partially unwatered trenches. It is almost impossible to get laborers to work efficiently in wet ground, and it is absolutely impossible to get masons to do a proper day's work under such conditions.

There are three general methods of unwatering trenches: (1) By pumping the water directly from its location in the trench; (2) by leading it from the place where work is being carried on to a natural or artificial sump, by means of a drain; and (3) by unwatering the site by "bleeding."

Direct Pumping. Where the flow of water does not exceed 50 gal. per minute, one man with a diaphragm pump will keep the trench clear. Where the flow does not exceed 75 gal. per minute a two-man pump is required. Edson diaphragm pumps, with 20 ft. of hose and strainer, cost $48 for the one-man size and $70 for the two-man size. For flows of 60 to 80 gal. per minute, a diaphragm pump operated by a gasoline engine is very efficient. It can be started in the morning and given little or no attention for the remainder of the day.

For removing greater quantities of water centrifugal or reciprocating pumps are generally used. Emmett Steece gives the prewar cost of a centrifugal pump and its operation as follows:

Centrifugal pump with 5-in. suction	$110
Timber framing	6
80-ft. of 9-in. belt	36
6-hp. gas engine	350
Total cost	$502

This engine uses 5.5 gal. of gasoline per 10-hr. day.

Pumping for Sewer Construction in New Orleans. Victor Windett gives the cost in 1911 of pumping with an 8-in. centrifugal pump. The work was the construction of a sewer in New Orleans. The pump was in constant service for 417 days. While steam was kept at operating pressure continuously, the pumping was intermittent during each 24 hr. The inflow of water required pumping for a total of 12 hr. each day. The labor charge was low, the men being paid $73.50 each per month, or 20 ct. per hr. There was one man to each 12-hr. shift tending the boiler and pump. The daily cost of operation was as follows:

Coal, 1.275 tons at $3 per ton	$ 3.80
Oil for lubrication and illumination	0.25
Supplies	0.15
Water tax	0.33
Repairs to pump and boiler	0.93
Depreciation	0.75
Wages	4.80
Total	$11.01
Overhead burden	1.34
Total daily expense	$12.35

The Pulsometer Pump. This pump has been used for trench pumping for 50 years. This pump, while uneconomical in steam consumption, is reliable, and, once started, requires almost no attention. One advantage of this pump is that it can be hung anywhere in a trench and requires no foundation. It has no moving parts except valves and requires no lubrication. It is made in various sizes by the Pulsometer Steam Pump Co., New York City.

A Tile Drain for Handling Water. *Engineering and Contracting*, Oct. 2, 1907, gives the following:

In the construction of a 66-in. reinforced concrete sewer, the material encountered in excavation was loose black soil for a depth of 24 ft., and sand and gravel, water bearing for about 5 ft. at the bottom. The average depth of the trench was 18½ ft., with a width of 10½ ft. To handle the water a subdrain, pump and sump were used. The pipe used for subdrain was second class and cull pipe, laid with the invert 30 in. below the invert of the main sewer. Joints were loosely calked with tufts of sod in order to hold back the fine sand, and the whole covered with clean gravel of medium size. The drain pipe emptied into a sump

at the lower end of the new work, which was about 18 in. below the subdrain grade, in which was a 6-in. centrifugal pump, used to discharge the water over a dam in the old portion of the sewer. By this method it was possible to put the concrete on a dry bottom. It was found necessary, however, to run the pump while the invert was being plastered, and it was kept going until the plastering was set, otherwise the water would force its way in from the outside and cause the mortar to slough down, leaving the bottom rough and the sides, to some extent, porous. The total cost of caring for the water was as follows per foot of sewer:

Subdrain pipe	$0.33
Labor laying drain pipe	0.35
Handling water	0.45
Total per ft.	$1.13
Cost per cu. yd. of excavation	0.115

The item handling water includes the fuel, housing and rental of pumping engine, pay of engineman, also sinking of two sump holes for the pump and filling up of same after the work was done. The engineman received $2 per 10-hr. day, and common labor received $1.85.

Pumping for Sewer at Harrisburg, Pa. *Engineering Record*, Oct. 15, 1904, gives the following:

The main sewers comprised 7,600 ft. of reinforced concrete section 12.3 sq. ft. in area, and 7,670 ft., 19.3 sq. ft. in area. Trenches were 8 and 9 ft. wide, and averaged 10.5 ft. in depth. Most of the work lay alongside Paxton Creek which was in flood several times. An excessive amount of water was everywhere encountered. To handle this an 8-in. underdrain was used almost the whole length of the work. It was laid with open joints, filled around with gravel, and connected with sumps at the side of the trench, from which the water was pumped. These sumps were about 6 x 6 ft. in size and were excavated at irregular intervals at the same time as the trench but 2 ft. deeper. At some places it was necessary to lay a double line of 8-in. underdrain. Six-inch direct-connected Morris centrifugal pumps were used. One pump was used for each section of the work, the pump being moved ahead, when necessary. The average length of section pumped was 550 ft., and the maximum 1,750 ft. The ground water level varied considerably but averaged 6 ft. above subgrade. A typical section yielded about 2,200 gal. per lin. ft. per 24 hr. The cost of pumping on the main trench, including the cost of underdrain, was about 36 ct. per cu. yd. of excavation, or $1.30 per lin. ft. of trench. Coal cost $3.80 per ton. A fireman attended each boiler and a boy each pump, day and night.

The material encountered was firm clay with occasional layers

of gravel, and covered with various kinds of top-soil. The greater part of the invert was laid on an underlying stratum of gravel. Very little solid rock was encountered.

In the streets and on level, dry land, where possible, a Jackson hoist was used, and the material excavated was carried on cars and dumped on the completed work. In deep cuts where the condition of the surface did not permit the use of the Jackson hoist, buckets and boom derricks were used. In shallow cuts excavation was done entirely by hand. The total excavation of the main line amounted to 54,465 cu. yd., and cost 71 ct. per cu. yd. About 38,587 cu. yd. were backfilled at a cost of 38 ct. per cu. yd. Common labor was paid 15 ct. per hr.

Tight sheeting, placed vertically, was generally required, but in shallow cuts, skeleton sheeting was used. Two-inch lumber was used. The rangers and cross braces were of wood. The sheeting cost about 87 ct. per lin. ft. of trench.

Unwatering by Use of "Bleeding Points." Otto Gersbach in *Engineering and Contracting*, June 5, 1907, gives a description of a method used at Indiana Harbor, Indiana, for drying out water bearing sand. This method is now frequently used in wet material and is commonly known as the method of "bleeding by points."

At Indiana Harbor, pipe sewers of 8 to 30-in. diameter were laid in sand to depths as great as 21 ft. After excavation had proceeded until ground water was reached, 2-in. iron pipes, 10 ft. long were driven down by the aid of a water jet operating at a pressure of 25 lb. per sq. in. These pipes were pointed, and were perforated just above the points, the perforations being covered with a fine wire netting in order to exclude the sand. The pipes were spaced 4 ft. apart as a rule, but 8 ft. in some cases. They were driven to a point below the grade of the sewer, sections 2 to 4 ft. long being used to lengthen the standard 10-ft. section where necessary. The pipes were driven in lines close to each side of the trench.

The driven pipes were connected by short lengths of hose to a 4-in. main pipe running lengthwise over the center of the trench and supported by plank. The 4-in. pipe was connected to a 10 x 6 x 12-in. duplex pump run by a 20-hp. boiler. Thus the trench was kept dry. Little or no sheeting was required as the damp sand did not run. A row of planking was placed at the top of the trench to keep back sand that might be pushed down by the men above.

Excavating Quicksand in Toronto. The methods used in excavating, sheeting and pumping trenches for 20 and 24-in. pipe sewers at North Toronto, Canada, are described by George Phelps,

in *Engineering and Contracting*, Dec. 25, 1912. Most of the trench was 30 ft. deep, and the nature of the material (quicksand and water at depths of 16 ft.) made the work very difficult and expensive. Further disadvantages were (1) the narrow working space which prevented the use of conveying and backfilling machines, (2) the great depth of cut, and (3) the cold weather.

The material was removed from the trench by hand in stages. When the excavated material was allowed to lie for some time it froze, and backfilling was necessarily expensive. Frost wedges and dynamite were used to break up some of the material.

The system of cross braces shown in Fig. 36 was adopted to prevent the collapse of the curbing. Extra diagonal braces were often put in as well, but even this did not always prevent the settling of the timber work with the falling sides. The timbering consisted of two settings of 2 x 6-in. pine runners, the top setting being 12 ft. deep and the bottom 16 ft. deep. The walings and struts were of 4 x 6-in. pine, and the cross braces of 2 x 6-in. pine. A uniform width of trench was kept and each setting of timber was 16 ft. in length, this being the length of walings used. The walings were about 4 ft. apart vertically, three on each side for a top setting and four for a bottom setting. The cross braces and 4 x 6-in. struts were placed at each end of the walings in addition to 4 x 6-in. struts in the middle, the timbering thus being divided up into 8 ft. bays. After the bottom setting of timber had been driven down to the full depth, the joints of the runners were covered with short lengths of 1-in. boards to keep back the sand as much as possible. This helped considerably but did not entirely prevent the sand from washing in.

The drawing of the timbers after the pipes had been laid was attended with some danger. The bottom setting was first drawn, often exposing big caves in the sides of the trench where the material had washed away. These, with the trench, were filled up to the bottom of the next setting before any of the top timbers were disturbed. On removing the struts from the top setting the sides of the trench often fell in from several feet back, to the great danger of the timbermen, but fortunately the work was completed without any serious mishap from this cause.

In passing the telephone poles which came immediately on the side of the trench, the top setting of timber was left in for safety. In addition stays were placed on the poles and left there after completion of the work to protect them from heeling over or sinking until the trench settled down quite firm. In some places where the ground was very bad, particularly at a point where the trench passed close to a grove of trees, the whole of the timbering was left in the trench. After filling such places a large amount

of surplus earth remained to be hauled away. The trenches have shown very little sign of settling down since being filled, and it is likely that the caves left behind the timbering where it was not drawn will silt up from underneath quicker than the filling material will find its way through from above.

Pumping was required at all times. At the beginning of the

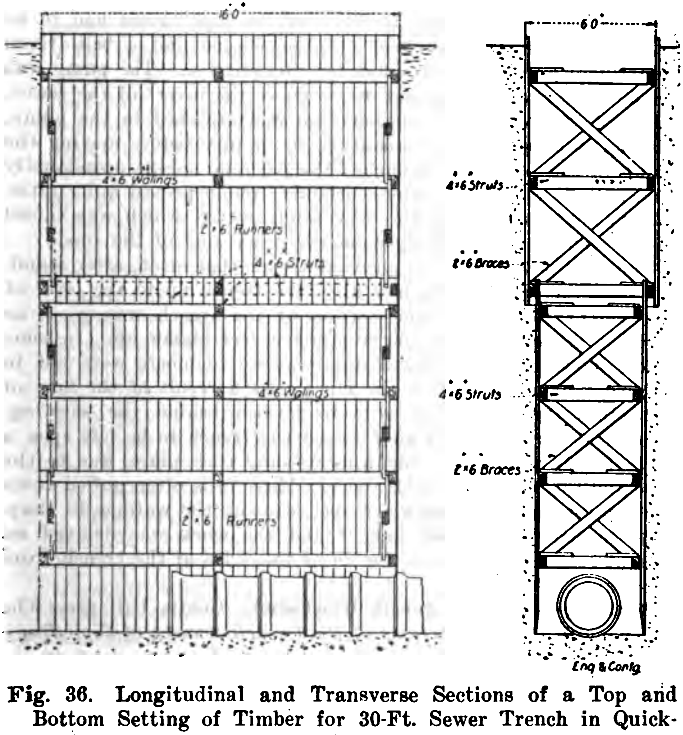


Fig. 36. Longitudinal and Transverse Sections of a Top and Bottom Setting of Timber for 30-Ft. Sewer Trench in Quicksand.

bad stretch a sump was located and the water was removed from this by a Pulsometer pump. In capacity it was found to be more than sufficient to deal with the quantity of water, and therefore it was worked intermittently. For this reason the sand that was carried by the water settled down on the valves during the periods of rest and there was often a delay in getting the pump to start again.

Shortly after the commencement of the work on the flat grade it was found impossible to keep the sewer free from the sand carried in suspension in the water, and being very fine, it quickly settled down in the pipes and formed an obstruction. Attempts were made by means of rods and chains drawn through to keep the pipes clear. Flushing from a hydrant also was tried. But the level of the water could not be kept down sufficiently to make good joints, and pumping in front of the pipe layers had to be resorted to. A 4-hp. vertical gasoline engine and a belt-driven centrifugal pump were provided for this purpose. The pump was set down in the trench about 10 ft. above the invert of the sewer. About 35 ft. of flexible suction hose was attached to the pump, making it possible to lay about 70 ft. of pipe before moving the pump further along the trench. The gasoline engine occasionally gave a little trouble, but the centrifugal pump proved quite satisfactory for dealing with the very sandy water, which was raised to the surface and discharged on the other side of the road.

The sand flowed so freely into the trench that often, after standing over the week-end, it had filled the trench up to the level of the top of the pipes. The bottom of the trench was good, as a rule. The quicksand came from a few feet higher up. In some places, however, where the bottom was soft, timbers were put in to give a firm bearing for the pipes. As a result of the flow of sand into the trench, caves were formed behind the sheeting. When a delay occurred which caused the trench to be left open a little longer than usual, big falls of sand took place, due to the cave and the weight of earth above. These falls often pulled down the top setting of timber a few feet, causing the walings to snap. This constituted a great danger and the work was delayed on several occasions by the caving in of the sides of the trench from this cause.

Building a Brick Sewer in Quicksand. Curtis Hill gives the following in the *Transactions of the Cornell Society of Civil Engineers* (1905). In St. Louis an oval-shaped sewer, 4 x 6 ft. in size, was constructed on a quicksand bed, the three lowest feet being in quicksand. The trench was excavated until quicksand was found when sheeting was driven first along the sides and then across the line of sewer to below subgrade, thus boxing off a section of quicksand. This was excavated as rapidly as possible, and burlap sacks, loosely filled with dry concrete, were placed in the bottom of the trench immediately and tamped into the sand. These sacks were placed slightly lapping one another, the outside ones resting upon the sheeting at the sides, and roughly conformed to the shape of the sewer invert. Nine or ten inches

of concrete gave a stable foundation and the brickwork was built directly upon it.

Solidifying Quicksand by Injecting Cement Grout. At Providence, R. I., according to *Engineering News*, Apr. 28, 1892, great trouble was experienced in 1891 in the construction of a large sewer in quicksand. The contractors were unable to proceed, and petitioned for cancellation of their contract, which petition was granted by the city council.

In the vicinity of the sewer a large section of wooded area about 150 x 75 ft. in extent sank several feet after a pump had been operating in the trench for 2 days. The trench had to be from 12 to 15 ft. wide and 20 to 30 ft. deep in quicksandy material saturated with water almost to the surface. The force of the flow of quicksand was almost irresistible, 4-in. splined spruce sheeting in a 30-ft. trench snapped off several planks at a time, and spruce struts were forced into the rangers.

An experiment was made with an invention of Robert L. Harris. Four pipes, 4 ft. apart, were driven to a depth of 17 ft. Water, forced down two of the pipes, washed out a chamber while seeking an outlet through the other pipes. A smaller pipe, with suitable valves, was then put down inside one of the larger pipes. When this small pipe extended below the outside of the larger pipe there was a free passage for fluid up or down. When the inner pipe was drawn up a little, it acted as a valve and closed the larger pipe. Cement grout, "doctored" with sand and plaster of Paris, was then forced down the smaller pipe. By repeating this a floor of concrete was formed.

Freezing Quicksand. Maurice Deutsch, in *Engineering News*, Jan. 30, 1913, describes the successful employment of the freezing process in the excavation of a building foundation in Berlin, Germany, where ordinary methods had previously proved a failure and had caused settlement of adjoining buildings. The material was quicksand, extending to considerable depth. The cellar excavation was carried a distance of 36 ft. below ground water level and 25 ft. below the foundations of the adjoining buildings.

Closed pipes, on 3-ft. centers, 5 in. in diameter and 5/16 in. thick, were driven vertically 59 ft. deep, around the site, 6.5 ft. from adjoining buildings. Inside these pipes was set a 1-in. brine pipe. Refrigerating brine was pumped down the 1-in. pipe and up the annular space between that pipe and the surrounding 5-in. pipe, at a velocity of 11.5 ft. per min. After four weeks, the ground was frozen sufficiently for excavation which was accomplished by dredging. The bottom of the excavation was covered with a thick bed of concrete placed under water.

Bleeding Wet Sand at Gary, Ind. *Engineering and Contracting*, Aug. 5 and Oct. 14, 1908, gives the following,

The sand at Gary, Ind., is very fine, and is such a sand as forms the dunes of Michigan and other states bordering Lake Michigan. When water soaked it slopes at a grade of 1 vertical to 15 horizontal. On the location of the work this fine sand was water soaked to within a few feet of the surface. In places the water covered the surface.

In constructing a brick sewer of oval section, 6 ft. 4 in. by 8 ft. 11 in. in size, the trench was dug to depths varying between 18 and 30 ft. A preliminary wide shallow cut was excavated first by a grab bucket and later by scraper bucket. For the first 1,900 ft. a ¾-cu. yd. Hayward orange-peel bucket, operated by a 25-hp. engine, was used. This machine removed 21,250 cu. yd. at the following cost.

Engineman, 56 days, at $6	$ 336.00
Fireman, 56 days, at $3.50	196.00
Laborers, 255 days, at $1.75	446.25
Coal, 56 shifts, at $5	280.00
Total	$1,258.25
Cost per cu. yd.	$0.059

At this point the orange-peel was removed to the rear to work on backfilling and a Page & Schnable drag scraper excavator was substituted. This machine had a 2-cu. yd. bucket and a 40-hp. engine. This engine was found to be too weak and was used only until a larger one could be secured. Another objection to the first arrangement was that two men were required to operate the bucket, one at the hoist and one at the swing engine. With the machine as first equipped and operated 15,300 cu. yd. of material were excavated at the following cost:

Engineman, 31 days, at $6	$186.00
Fireman, 31 days, at $3.50	108.50
Engineer, 31 days, at $3	93.00
Laborers, 118 days, at $1.75	206.50
Coal, 31 shifts, at $5	155.00
Total	$749.00
Cost per cu. yd.	$0.049

The 40-hp. engine was replaced by one of 60-hp., so arranged that one man operated both hoist and swinging engine. With the remodeled outfit 11,000 cu. yd. of material were excavated at the following cost:

Engineman, 21 days, at $6	$126.00
Fireman, 21 days, at $3.50	73.50
Laborers, 84 days, at $1.75	147.00
Coal, 21 shifts, at $5	105.00
Total	$451.50
Cost per cu. yd.	$0.041

It will be seen that the change of engines reduced the cost per cubic yard by the amount of the wages of one engineman; the saving was 0.83 ct. per cu. yd. Summarizing we have a cost of $2,488 for excavating 47,550 cu. yd., or of 5.23 ct. per cu. yd. For the 4,258 ft. of sewer the cost was 57.9 ct. per lin. ft. The machine was mounted on rollers traveling on a track of timbers. One merit of the machine was that some of the excavated material could be dumped straight ahead in the path of the work so that it built its own roadbed over the swamps in front. The machine was pulled ahead by simply lowering the bucket and letting it get a good bite in the ground ahead, then pulling on the digging cable.

When the scraper bucket had excavated to water level the ground water was partially removed by the method known as "bleeding." This method proved eminently successful. It enabled sand that normally flows at a slope of 1 on 15 to be excavated in narrow trenches to some 22 ft. below water level with only ordinary rough sheeting reaching to a point 6 ft. above the bottom. So important a factor in the successful prosecution of the work was the "bleeding" that, according to one of the engineers on the work, had the pumping been stopped for half an hour the trench would have been dangerous to work in.

The method of bleeding was essentially as follows: A 4-in. pipe, 132 ft. long, in six 22-ft. sections, stretched along the center line of the sewer. On each side of this pipe, about 3 ft. away, is sunk a row of well points 2 ft. apart. These well points are 3 ft. long and are attached to 13-ft. pipes. The tops of the driven pipes are connected by hose to the 4-in. pipe line which has cross-valves for the purposes. A pump connects with the 4-in. pipe line and also with a 4-in. well point sunk vertically underneath. An extension of the 4-in. pipe line with strainer end also takes the surface water from a sump.

This battery of well points lowers the water so that a further excavation of 6 to 8 ft. can be made between sheet piling. A second battery of well points is then sunk at this new level. In this battery, however, the points are sunk close to the sheeting, and each row feeds into a separate 2-in. pipe along the trench. This battery lowers the water level enough to permit excavation to sub-grade, which is some 6 ft. below the bottom of the sheeting. The brick sewer is then built in the usual manner and the back-filling is done by means of a derrick and Hayward clam-shell bucket.

Fig. 37 shows the general plan of procedure described. It was noted that the vacuum type of pump seemed to be particularly

successful owing to its ability to work with a large amount of air in the suction and to its ability to handle gritty water.

Referring to Fig. 37 it will be seen that the first battery of well points occupies a narrow space along the center of the trench; this permits the sheeting to be driven outside of the

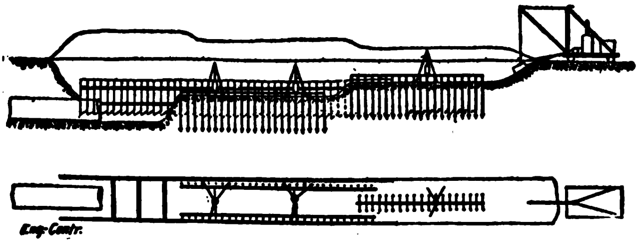


Fig. 37. Scraper Excavator on Trench Work.

well points. The well points are 2 in. x 3 ft., and they are attached to 2-in. x 13-ft. pipes with ells at their tops. A 4-ft. length of wire-lined hose is attached to each ell. These points are sunk vertically by jetting. Points of similar type but of less diameter that were used on a narrow trench are illustrated in Fig. 38.

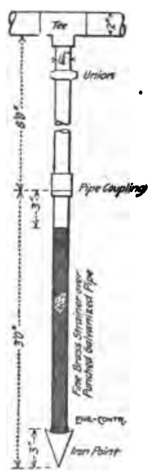


Fig. 38. Pump Point for "Bleeding."

Two men were timed in jetting. They used 1-in. jetting pipes with about 100 lb. water pressure and sunk four points in one minute. This time did not include making connections. In addition to the two rows of 2-in. points, a 4-in. point is sunk directly under the pump.

The well points are connected by the short hose lengths to a 4-in. horizontal suction pipe. Six 22-ft. sections of suction pipe are used with flanged joints. Each section has 11 cross-valves with double bushings for the hose connections. A gate valve near the end of each section permits the rear-sections to be removed and placed ahead as fast as the work progresses. An extension of the 4-in. suction pipe forward to a sump in the excavation being made by the scraper bucket handles the surface water.

The water is drawn from the suction pipe by an Emerson No. 3 pump with 5-in. suction and 4-in. discharge. The pump is hung to a chain fall from an A-frame mounted on rollers. It discharges into a tile drain alongside the trench; this drain leads back to the completed sewer discharging behind a temporary dam of bags of sand inside the sewer. Summarized, the first battery of well points is composed as follows:

One No. 3 Emerson pump; 1 (4-in.) well point sunk below pump; 132 (2-in.) well points sunk in two rows; 1 (4-in.) suction pipe with extension to surface water sump. The trench was sheeted 10 ft. wide, the sheeting being carried along so as to embrace about one section (the rearmost) of the first battery of well points. The sheeting was 2 x 8-in. x 12-ft. planks and is driven by mauls. Waling pieces and trench braces were placed as the excavation proceeded. This excavation was carried down about 6 ft. by shovelers, and at this level the second battery of well points was placed. The sheeting was pulled as the backfilling proceeded.

The second battery of well points consisted of two rows like the first, but the rows were placed wide apart (close inside the sheeting on both sides) and each had a separate suction pipe. The suction pipes were 2 in. and the well points 1¼ in. in diameter. The well points and pipes were 16 ft. long, and when sunk they penetrated about 2 ft. below sub-grade and 6 ft. below the bottom of the sheeting.

Two pumps similar to those used for the first set of points operated this battery. Each drew water from both rows of well-points and also from a 4-in. well point sunk directly under the pump. From a 4-way connection, 2-in. pipes branched right and left to connections with the 2-in. suction pipes. A third connection was made to the 4-in. point. The pumps could concentrate their work on one portion of the battery or could pump from the

entire system. The pumps discharged into the same drain as the first pump. The methods of advancing the second battery were substantially the same as for the first set of well points. Generally the forward end of the second battery was kept far enough ahead to overlap the rear section of the first battery.

The pumping was continuous day and night, but the jetting of well points and changing of piping was confined to the regular shift of 9 hr. In this method of pumping it is important to keep lowering the points as the excavation deepens. If the points are driven to bottom grade at the beginning of the excavation work, an unnecessarily large amount of material must be unwatered.

The item of pumping comprises all the work of sinking and shifting the well points and pipe line and the removal of the backwater in the finished part of the sewer. Three Emerson pumps took water from the well points, a fourth handled the backwater and a duplex pump furnished water for boilers, mixing mortar, jetting, etc. The cost was as follows:

Laborers, 542 days, at $1.75	$ 948.50
Pipe line men, 958 days, at $2.50	2,395.00
Total for pipe work	$3,343.50
Coal, 100 days, at $15	$1,500.00
Firemen, 855 days, at $3.50	2,992.50
Total for pumping	$1,492.50
Grand total	$7,836.00
Cost per lin. ft.	$1.837

Pumping costs and pipe line costs have been separated, since the first in a continuous expense which does not vary from day to day, and the second cost is operative only when construction is actually going on.

Hand Excavation. The bottom 13 ft. in depth of the trench was excavated by hand between sheeting; the width of the excavation was approximately 10 ft. The cost of the work was as follows:

Laborers, 6,441 days, at $2	$12,882.50
Foreman, 84 days, at $3	522.00
Total	$13,434.00
Cost per cu. yd.	$0.565

The total amount of hand excavation was 23,800 cu. yd.

Sheeting. The sheeting consisted of vertical 2 x 8-in. by 12-ft. planks held by two pairs of 6 x 8-in. waling pieces and 9-ft. cross braces spaced 8 ft. apart. In cases of very wet trench a third row of waling and braces was put in; occasionally, also, horizontal sheeting was used in the bottom. Sheeting was driven to within 6 ft. of the trench bottom. The cost of driving the sheet-

ing and placing the bracing and also of pulling it was as follows:

Placing:	
Laborers, 882 days, at $2	$1,764
Foreman, 80 days, at $3.50	280
Carpenters, 50 days, at $3	150
Total	$2,194
Pulling:	
Laborers, 242 days, at $2	484
Total	$2,678
Cost per lin. ft.	$0.629

The materials were hauled 1,500 ft. in steel dump cars running on portable track; the cars were pushed by hand. Coal, lumber, supplies, etc., purchased from local dealers, were hauled by team. The cost of hauling was as follows:

Laborers, 1,219 days, at $2	$2,438
Foreman, 80 days, at $3.50	280
Teams and drivers, 180 days, at $5.50	990
Total	$3,708
Cost per lin. ft.	$0.87

The construction of the 4,258 ft. brick sewer was as follows:

Laborers, 1,506 days, at $2	$ 3,012.00
Carpenters, 50 days, at $3	150.00
Form setters, 225 days, at $3.75	843.75
Bricklayers, 471 days, at $10	4,710.00
Scaffold men, 236 days, at $2.75	649.00
Brick tenders, 236 days, at $3.75	885.00
Mortar mixers, 387 days, at $2.25	860.75
Total	$11,110.50
Cost per lin. ft.	$2.609

As noted further on, the cost of brick and cement for the job was $14,436.50, or $2.384 per foot of sewer, making the total cost for labor and material $4.993 per lin. ft. Since there were 520 bricks per lin. ft. of sewer, the cost per cubic yard of the brickwork was approximately the same as the cost per lineal foot. The bricklayers averaged 4,710 bricks per man per 9-hr. day. Two barrels of cement were used per 1,000 bricks.

Enough backfilling was done by hand to cover the sewer and to permit the sheeting to be pulled; the remainder was done with the clam-shell excavator first used for preliminary trenching. The cost of backfilling by hand was as follows:

	Per lin. ft.
Laborers, 378 days, at $2	$0.18

The cost of backfilling by machine was as follows:

Laborers, 307 days, at $1.75	$ 537.25
Engineers, 93 days, at $6	558.00
Firemen, 93 days, at $3.50	325.50
Coal, 93 shifts, at $5	465.00
Total	$1,885.75
Cost per lin. ft.	$0.440

The cost of the materials used in the job was as follows:

2,221,000 brick, at $5	$11,105.00
Utica cement, 6,663 sacks, at 20 ct.	1,332.60
Universal cement, 6,663 sacks, at 30 ct.	1,998.90
30 M. ft. B. M. lumber, at $20	600.00
Total	$15,036.50
Cost per lin. ft.	$3.529

The costs of superintendence and general expenses were as follows:

Superintendence:	
Superintendent, 4 mo., at $150	$ 600
General foreman, 4 mo., at $125	500
Master mechanic, 4 mo., at $200	800
Timekeeper, 3 mo., at $60	180
Team, 100 days, at $4	400
Total	$2,480
General Expenses:	
Waterboys, 220 days, at $1.50	$ 330
Clearing right of way, 60 days at $150	90
Total	$ 420
Cost per lin. ft.	$0.099

Summarizing we have the cost per lineal foot of sewer as follows:

Excavation by machine	$ 0.58
Excavation by hand	3.15
Sheeting	0.63
Hauling brick and other materials	0.87
Pumping	1.84
Laying brick sewer	2.61
Backfilling by hand	0.18
Backfilling by machine	0.44
Materials	3.53
Superintendence and general	0.68
Depreciation, repairs, setting up machines	1.50
Making 3 railway crossings $2,500)	0.58
Total per ft.	$16.59

The work was begun on April 2 and was completed on Aug. 5, 1908, during which time only 11 days were lost by the bricklayers.

Cost of a Sewer in Quicksand at Gary, Ind. The following is given in *Engineering and Contracting*, Jan. 27, 1909:

A 66-in. brick sewer was constructed at Gary, Ind., by methods similar to those used for constructing an oval sewer described above. The land consisted of alternating ridges and marshes differing in elevation about 10 ft. The trench, therefore, varied in depth from 14 to 24 ft., averaging 17 ft. The material was a fine sand saturated with water to a height of 13 or 14 ft. above the trench bottom.

Construction was begun Aug. 1 and finished Oct. 1, 1908. Laborers on excavation, sheeting, pumping, etc., worked a 10-hr. day; tenders, cement mixers and helpers to bricklayers worked a 9-hr. day; bricklayers worked an 8-hr. day; firemen on pumps worked in 12-hr. shifts, and excavating machine crews worked a 9-hr. day. The costs of the various items of the work were as follows.

Drag Bucket Excavator Work. The preliminary cut was about 30 ft. wide and from 4 to 10 ft. deep; there were 33,350 cu. yd. of excavation for the 4,062 ft. of sewer or about 8.21 cu. yd. per lin. ft. The excavator worked 83.5 shifts and so averaged nearly 400 cu. ft. per shift of 9 hr. The cost of operating the excavator was as follows:

1 engineman, at $6	$ 6.00
1 fireman, at $3.50	3.50
4 laborers, at $2	8.00
Coal (estimated)	5.00
Oil, repairs, etc.	2.00
Total per 9 hr.	$24.50

This gives a cost of 6.1 ct. per cu. yd. of excavation and of 50.3 ct. per lin. ft. of sewer.

Excavation by Hand. The excavation between sheeting, approximately 8½ x 10 ft., was done by hand, scaffolding the material from 3 to 5 times and an average of 4 times. The cost of the work was as follows:

Foreman, 51 days, at $3.25	$ 165.75
Laborers, 2,184 days, at $2.25	4,914.00
Total	$5,079.75

This gives a cost of 39.4 ct. per cu. yd., and of $1.25 per lin. ft. of sewer.

Pumping. The pumping plant consisted of 3 No. 3 Emerson pumps drawing from the well points; 1 No. 2 Emerson pump taking water from the pools formed behind the drag bucket excavator; 1 duplex pump for boiler feed, jetting points, wetting brick, etc., and 4 30-hp. horizontal boilers mounted on wheels. This plant worked continuously. The cost of operation was as follows:

Laborers, 464 days, at $2	$ 928.00
Fireman, 439 days, at $3.50	1,536.50
Pipe linemen, 1,238 days, at $2.50	3,094.00
Foreman, 27 days, at $3.50	94.50
Coal, 60 days, at $15 (estimated)	900.00
Total	$6,553.00

This gives a cost per lineal foot of sewer of $1.61 for pumping. Charged entirely against the excavation between sheeting which was closely 12,893 cu. yd., the cost of pumping per cubic yard of excavation was 50.8 ct.

Sheeting. The sheeting consisted of 2 x 8-in. x 12-ft. plank driven close on each side of the trench. This sheeting was braced apart by two 6 x 8-in. waling pieces set 3 ft. apart vertically and 6 x 8-in. x 8½-ft. cross-braces spaced 8 ft. apart along trench. The cost for sinking, bracing, pulling and bringing forward was as follows:

Labor, placing and driving, 392 days at $2.25	$ 882.00
Labor, pulling and bringing ahead, 182 days, at $2.25	409.50
Foreman, 27 days, at $3.50	94.50
Carpenter, 36 days, at $3	108.00
Total	$1,494.00

This gives a cost for sheeting of 36.8 ct. per lin. ft. of trench and of 11.6 ct. per cu. yd. of excavation between sheeting. There were about 73 ft. B. M. of sheeting and bracing per lineal foot of trench, so that the cost per M. ft. B. M. was practically $5 for labor placing, pulling, etc.

Laying Brick Sewer. The sewer was built of two rings of brick. The invert was built in 24-ft. sections. Wooden centers with lagging 16 ft. long were used in laying the arch and 2 men knocked the centers down, brought them forward and re-erected them as fast as 6 bricklayers could work. The cost of laying was as follows:

Bricklayers, 223 days, at $10	$2,230.00
Tenders, 112 days, at $3.75	420.00
Scaffoldmen, 111 days, at $2.75	305.25
Mortar mixers, 225 days, at $2.50	562.50
Form setters, 100 days, at $3.75	375.00
Laborers, 715 days, at $2	1,430.00
Carpenter, 18 days, at $3	54.00
Total	$5,376.75

This gives a cost of $1.32 per lin. ft. of sewer and of $5.28 per 1,000 bricks laid.

Backfilling. The backfilling to a height of 2 ft. above the brickwork was done by hand, and for the remainder of the height by a 1-cu. yd. Hayward clam-shell excavator. The backfilling by hand

called for 277 days' labor at $2 and cost, therefore, $554 or 13.6 ct. per lin. ft. of sewer. The cost of the clam-shell excavator work was as follows:

1 engineer, at $6	6.00
1 fireman, at $3	3.00
3 laborers, at $2	6.00
Coal (estimated)	5.00
Oil, repairs, etc.	2.00
Total per day	$22.00

There were 55 shifts worked giving a total cost of $1,210. In addition the drag bucket excavator was worked backfilling for 18 shifts at $24.50, making a total of $441. Lumping the work of both machines, the cost of backfilling was 40.6 ct. per lin. ft. of sewer and 6.8 ct. per cu. yd.

Materials. The cost of materials was as follows:

1,018,000 brick, at $5 per M.	$5,090.00
3,054 bags Utica cement, at 20 ct.	610.80
3,054 bags Universal cement, at 35 ct.	1,065.90
Lumber (estimated)	600.00
Total	$7,369.70

This is a cost of $1.81 per lin. ft. of sewer.

Hauling Materials. For about 3,000 ft. of the work all materials were hauled from the railway siding in 2-cu. yd. steel dump cars running on narrow gage track. The average haul was 1,700 ft. For the remainder of the work the hauling was done with teams; brick were hauled by subcontract for 70 ct. per M. Two teams were also employed throughout the work to haul supplies from local dealers and to haul coal to the excavators when they were beyond reach of the contractors' railway. The cost of hauling was as follows:

Laborers, 767 days, at $2	$1,534.00
Foreman, 52 days, at $3.50	182.00
Brick, hauled by team at 70 ct. per M.	194.60
Teams, 100 days, at $5.50	550.00
Total	$2,460.00

The cost of hauling was thus 60.7 ct. per lin. ft. of sewer.

Superintendence and General Expenses. The costs under these items comprised the following:

Superintendent, 2 months, at $150	$ 300.00
General foreman, 2 months, at $150	300.00
Master mechanic, 1 month, at $200	200.00
Clearing right of way	80.00
Waterboys, 160 days, at $1.50	240.00
Handy teams, 52 days, at $3	156.00
Total	$1,226.00

This gives a cost of 30 ct. per lin. ft. of sewer.

Summary. Summarizing the costs of the work per lineal foot of sewer we have:

Drag bucket excavation	$0.503
Hand excavation	1.250
Pumping	1.610
Sheeting	0.368
Laying sewer	1.320
Backfilling by hand	0.136
Backfilling by machine	0.406
Materials	1.810
Hauling materials	0.607
Superintendence and general	0.300
Depreciation of plant, repairs, etc. (estimated)	1.500
Total per ft.	$9.810

Draining Quicksand by "Bleeding." Frank I. Barrett, in *Engineering News*, Sept. 25, 1913, describes a method used for carrying a 22 x 40-ft. opening through an 8-ft. bed of quicksand 35 ft. below a river bottom. The quicksand was so soft that a man could not stand on it, and water boiled up under sheeting that had been driven 12 ft. below the top of the sand. The method successfully used was to fasten at the inner side of the sheeting, 19 ft. above grade, a 6-in. pipe header, with T-joints and valves spaced 3 to 5 ft. apart. To these Ts were connected 2-in. pipes with 60-mesh well points, 3 to 4 ft. long, driven 6 in. below grade. The water was removed from the header pipe by a 6-in. duplex pump. A second pump, with a large supply of spare valves, stems, etc., was kept in reserve. The pit was dry after 9 hr. of pumping and was excavated in 12 hr.

Pumping Quicksand from a Trench. A description of the methods and costs of constructing pipe sewers in quicksand at Wildwood, N. J., is contained in *Engineering and Contracting*, June 3, 1908. The land originally was covered at high tide by 3 ft. of water, but had been filled in above high tide level by dredged material. The original soil was black mud covered with thick meadow sod, with, here and there, piles of sand which were shifted by the tide.

The trench for the entire distance, 12 miles, was through quicksand, from which water bubbled, and known locally as "boiling sand." This made both expensive and difficult work, adding to the cost of laying the pipe, as it was difficult to keep the pipes at the proper grade and in good alignment, and the joints were hard to caulk, owing to the water in the ditch.

The greatest cutting was 6½ ft. deep and the entire trench was double sheeted throughout, great trouble being experienced in keeping the trench even partially dry. Sumps or wells could not be made, as the pumps pulled out so much sand under the sheet-

ing as to cause either the ditch to fill or the sheeting to cave in.

The sheeting was put down to a depth of 10 ft. with a water jet in advance of the excavation, this being the only way the contractor could make any headway. Owing to the numerous "salt holes" encountered, through which the line at times ran, it was necessary to make a foundation for the manholes and pipe. This was done by piling spaced 7 ft. apart and 6 in. c. to c. On the piles 4 x 4-in. yellow pine, 8 ft. long, was spiked, and to this were spiked hemlock planks 2 x 8 — 12 ft. long. The pipe was laid on this and the hole filled with sand and salt hay.

If a manhole was located at one of these "salt holes," 4 piles, 10 to 15 ft. long were driven 4½ ft. c. to c. Four railroad ties were then spiked together with two pieces of batten, and the whole bolted securely to the piles. On this foundation was placed a box 5 ft. square and 10 in. deep, the bottom being covered with tongue and grooved floor boards, and in some cases lined with canvas and the inside covered with coal tar pitch. The concrete was placed in the box, the pipe line run through, and the brick work completed.

As a general rule, water was struck in excavating the trench about 18 in. below the surface. The pipe laid was 8 and 12-in. terra cotta, hence the ditch was made only wide enough for a man to work in it easily, this width being 2 ft. for a ditch 6 to 7 ft. in depth.

The method of excavating was as follows: By using the piston pump the sheathing was put down for a distance of 150 ft. along the trench, and a closure made at each end. Then 10 laborers were put in the trench and excavation made to the water line, when rangers and braces were set.

The piston pump was then started pumping water into this "land coffer dam." A centrifugal pump was moved into position, and the discharge pipe placed midway in the last section, where the sewer pipe had already been laid. Thus the centrifugal pump excavated the material from the forward section and backfilled the last section at the same time. See Fig. 39.

When grade was reached, the foundation piles were jetted down and the cradle constructed. The pipe was then laid, the joints being made with cement and tar. The next section was then done in the same manner.

The sand excavated was quite coarse, and but little agitation was necessary with shovels, in order to allow the pump to pick up the sand. When the sand is fine grained, much more water is needed, and likewise the sand must be agitated with shovels. With extremely fine sand, the men must be relieved frequently, as

the work is hard, and, as the pumps take up a much smaller percentage of the sand, the ditch must be kept with a larger amount of water in it, and the men, being compelled to stand in the water, feel the effect of it quickly.

At times when the contractor got as deep in the trench as the original ground surface, he encountered a considerable number of roots that had to be cut out, but this was seldom necessary.

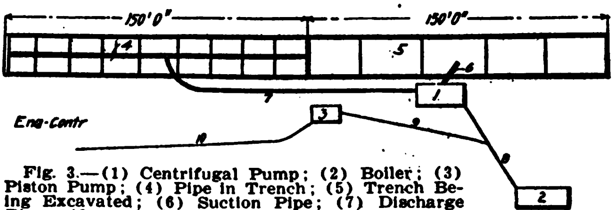


Fig. 3.—(1) Centrifugal Pump; (2) Boiler; (3) Piston Pump; (4) Pipe in Trench; (5) Trench Being Excavated; (6) Suction Pipe; (7) Discharge Pipe; (8) and (9) Steam Pipes; (10) Pipe to Water Supply.

Fig. 39. Arrangement of Plant for Excavation in Quicksand.

Fig. 39 shows the layout of the plant to do the work in the manner described. In this way an average of 300 lin. ft. of trench was dug and pipe laid per day, while another contractor doing similar work by another method averaged only from 35 to 50 ft. per day.

The cost of driving the sheeting and pulling it for the 300 lin. ft. of trench done per day was:

Boss timberman	$ 2.50
Fireman on jet pump	1.50
One man setting sheeting	2.00
Two helpers, at $1.50	3.00
Three men pulling sheeting, at $1.50	4.50
One man carrying sheeting	1.50
Two men bracing trench, at $2.00	4.00
One man pumping	1.75
Coal and oil	1.00
Total	$21.75

This gives a cost per lin. ft. of trench of 7 ct. for driving and pulling sheeting, and as there was 6,080 lin. ft. of sheeting driven and pulled a day, it makes a cost per lin. ft. of sheeting ⅓ ct. With 2-in. sheeting used, the amount of timber was 6,000 ft. B. M., which cost $26 per M. This timber, being driven with a water jet, was used time and time again. The sound piles, which were from 10 to 15 ft. long, cost 25 ct. apiece, and the cost of driving them was 1.5 ct. per lin. ft.

The cradle for the pipe was built by two men, each at $2 per day. They built 200 lin. ft. per day, which meant a cost per ft.

of trench of 2 ct. The amount of lumber in 200 ft. of cradle was 866 ft. B. M., which meant a labor cost for framing of about $5 per M. The lumber cost $26 per M.

The daily cost of digging the trench and backfilling, and of laying the pipe was:

Foreman, 10 hr.	$ 4.00
Eight men digging, at $1.50	12.00
Two men trimming, at $1.50	3.00
One engineman	3.00
One pumper	2.50
Two pipemen, at $2.00	4.00
Coal, at $5.00 per ton	1.25
Rent of boiler	2.00
Rent of pumps	2.50
Rent of engine	2.00
Two pipelayers, at $2.00	4.00
Two pipe carriers, at $1.50	3.00
One man on mortar and jute	1.50
Total	$44.75

Each day this plant excavated about 200 cu. yd., hence the cost of excavation per cu. yd. was:

Labor	$0.047
Coal	0.006
Plant rental	0.032
Total	$0.085

This is equivalent to 5.8 ct. per ft.

This is a very low cost for excavating earth from a trench and backfilling it.

The terra cotta pipe cost 16 ct. per lin. ft. and the hauling of it cost 2 ct.

The total cost per lin. ft. of pipe laid was as follows, exclusive of manholes:

Foreman	$0.013
Excavating and backfilling by hand	0.050
Excavating and backfilling by pump:	
Labor	0.032
Coal	0.004
Plant rental	0.022
Driving sheeting	0.040
Bracing trench	0.013
Pulling and carrying sheeting	0.020
Piles in place	0.105
Cradle, lumber and labor	0.132
Pipe	0.160
Hauling pipe	0.020
Laying pipe	0.028
Materials for joints	0.013
Total per ft.	$0.652

This cost does not include any allowance for general expense nor for the materials used in shoring the sides of the trenches. The

sheeting was used many times, as driving the planks with a water jet did not injure the planks or break them up.

The cost of this work in a ground difficult to excavate is exceedingly low, and can be attributed to the methods used in carrying on the work.

Backfilling Trenches. Backfilling on sewer work is not often given the consideration that its importance warrants. If the excavated material is placed on both sides of the trench it is sure to be walked over and compacted, often requiring picking before it can be thrown back into the trench. One man can backfill 20 cu. yd. of loose material in 10 hours.

It is frequently specified that there be one man ramming the earth for each two men shoveling. A man will ram 40 cu. yd. of loose earth in a day. In heavy clays, two rammers to a shoveler are often required.

It is a mistake not to tamp around the pipe. This is often omitted because of fear of deranging the alignment or disturbing the joints. There is more danger of this being done through uneven settling of the backfill if this tamping is omitted. Tamping around pipe should be done carefully with a light wooden tamper.

It is well to remember that the man tamping can consolidate almost as much earth with his feet as with the ram, and that it is of advantage to have him keep moving around.

A very common method of compacting earth in trenches is by puddling it with water. This is usually cheap and effective. Care must be taken not to puddle before cement work has had time to set. Puddling should not be attempted in unstable materials, such as muck or quicksand, where the trench bottom will become softened with the water and disturb the alignment of the pipe.

There are a number of ways of backfilling trenches besides doing it by hand. Plows and scrapers of various kinds are used with success on small trenches. In open fields the bank carrying the excavated material can be caved in with a hose and water, thus filling and compacting at the same time. Work done in this manner will require finishing by hand or with scrapers. There are a number of light traction machines on the market, on the order of dragline excavators, which are especially designed for backfilling trenches.

Where backfilling is done under paved streets the proper compacting of the fill is of great importance. This is a most fruitful source of dispute between the "city" and the "contractor." Valuable suggestions for avoiding this trouble will be found in the following abstract:

Backfilling for Water Pipe. At Corning, N. Y., a trench for a 10-in. water pipe was excavated 2½ ft. wide × 5 ft. deep, × 1,500 ft. long = 600 cu. yd. in 4½ days by 24 men, or at the rate of 6 cu. yd. per man per 10-hr. day, equivalent to 11 ct. a running foot or 25 ct. a cu. yd. The backfilling was done in 3 days by 2 men and 1 horse with driver, using a drag scraper and a short length of rope so that the horse worked on one side of the trench while the two men handled the scraper on the opposite side, pulling the scraper directly across the pile of earth. In this way 200 cu. yd. of backfilling was made per day at a cost of 2½ ct. per cu. yd., there being no ramming of the backfill required. This is a remarkably low cost for backfilling, and one not ordinarily to be counted upon. The material was a loamy sand and gravel.

At Rochester, N. Y., size of trench and kind of material practically the same as at Corning:

1 man excavated 8 cu. yd. a day at cost of 19 ct. cu. yd.

1 man backfilled 16 cu. yd. a day at cost of 9 ct. cu. yd.

Total cost of excavation and backfill 28 ct. cu. yd.

Backfilling Trenches Under Paved Streets. In *Engineering and Contracting*, Oct. 9, 1907, George C. Warren gives the following recommendations for backfilling trenches:

In the case of permits to service corporations, plumbers and property owners, to cut into the streets, whether paved or unpaved (the former is but little more important than the latter), it is only necessary to stipulate in the permit that "The trenches shall be backfilled by such means as the city engineer may direct, depending on the character of the excavated material, in such a manner that all excavated material shall be replaced in the trench without raising the grade of the roadway. Flushing will only be permitted in cases where the sub-soil is sand or gravel or other material from which the surplus water will readily drain away, and in the case of concrete or brick sewers or pipe sewers, the joints of which have been made water-tight with bituminous cement pipe jointing cement."

In the case of contract work for sewers, etc., the case is more difficult in view of the necessary uncertainty of conditions to be met underground, and consequent uncertainty of the most economical way to properly "back fill" the trench and consequent impracticability of the contractor accurately figuring in advance what the cost per lin. ft. will be. On this account some contractors are sure to bid far too low to permit proper work. Others figure "safe" with the probability that if they receive the contract, the total price will be too much above the estimated cost. In one case the city has the almost impossible task of

forcing the contractor to do proper work at a loss. In the other case the city will pay too much for the work. An effort should be made to avoid both evils.

My suggestion is to apportion the prices in such a way that whatever material is encountered a fair price will be allowed the contractor for each as follows:

(a) Furnishing and setting pipes per lin. ft.

(b) Earth excavation per lin. ft. (providing for varying prices for varying depths of sewer).

(c) Rock excavation per lin. ft. (providing for varying prices for varying depths of earth).

(d) Hauling excavated material to spoil bank (if unsuitable for backfilling and its removal directed by the engineer) per cu. yd.

(e) Lumber delivered on work (if any is required for shoring) per M. B. M.

(f) Placing and replacing (if lumber reused) in sewer trench per M. B. M.

(g) Refilling trench by flushing earth excavated from trench per cu. yd.

(h) Refilling trench by tamping earth excavated from trench per cu. yd.

(i) Refilling trench by flushing suitable borrowed material (to replace unsuitable excavated material drawn to spoil bank by order of engineer) including furnishing the material per cu. yd. measured in the wagons as material is delivered.

(j) Refilling trench by tamping suitable borrowed material (conditions the same as item "i"), per cu. yd.

(k) Refilling trench with rock excavated from the trench per cu. yd.

Corresponding with such a schedule of prices in proposal and contract, the specifications should provide as follows:

1st. Material excavated from the trench, which in the opinion of the engineer is unsuitable for backfilling, shall be hauled by the contractor to a spoil bank and shall be paid for at the price bid per cu. yd. for "hauling excavation to spoil bank," measurement to be made in the wagons at point where loaded.

2d. Flushing in back filling will be permitted only in case the material is sand or gravel or other material, from which in the opinion of the engineer the surplus water will readily drain away and leave the earth filled solid.

3d. Except where flushing is directed by the engineer, the backfilling shall be done by thorough, hard tamping in layers not exceeding six (6) inches in depth. Flushing will not be permitted except in cases of brick or concrete sewers or pipe sewers, the

joints of which have been made water-tight with bituminous pipe jointing cement.

4th. Whether backfilling of earth is done by flushing or tamping the full amount of material excavated from the trench, less the volume of the sewer, shall be refilled into the trench without raising the grade.

5th. In case rock is excavated from the trench, it shall be backfilled by carefully placing the excavated rock in layers with succeeding layers of earth well flushed into the voids between the pieces of placed rock.

6th. In case the excavated material is clay, which in the opinion of the engineer is too wet to enable solid backfilling by tamping, the excavated wet clay and reasonably dry "borrowed" earth shall be tamped into the trench in succeeding layers, using enough of the dry earth to overcome the excess of water in the clay and to provide a solidly filled trench to the satisfaction of the engineer. The "borrowed" earth including tamping, to be paid for per cu. yd. of "borrowed material" tamped into the trench. Measurement of the borrowed material is to be made in the wagons as delivered on the work.

Handling Backfill in Freezing Weather. The following instructions given by C. P. Chase, City Engineer, Clinton, Iowa, were published in *Engineering and Contracting*, Aug. 4, 1909.

(1.) It is much cheaper to thaw out ground with fire or steam than to pick frost.

(2.) Watch frozen banks for caving when frost goes out. It will drop all at once.

(3.) In backfilling frozen ground allow 20% more shrinkage than when dry. (This does not apply to rock.)

(4.) Cover all work as fast as laid with unfrozen earth, if possible.

(5.) Backfill and clean up as close to work as possible before excavating materials freeze.

Methods and Cost of Backfilling. The cost of backfilling depends upon the nature and condition (whether frozen, wet, packed, or dry powder) of the material, the means employed for backfilling, and the amount of tamping required. If the material is left in the spoil pile for some time and is subject to rain and the trampling of men and horses, it may become so consolidated as to cause the backfilling to cost almost as much as the original excavation. When backfilling by hand the men should not stand upon the pile and shovel from beneath their feet, but should stand at the edge of the trench or ditch and should excavate the material by pushing their shovels under it. When the ground surface is very rough it will pay to lay down steel "slick sheets"

for the excavated earth to be thrown upon. This will later materially decrease the cost of backfilling, as it is very much easier to slide the shovel along the smooth surface of the "slick sheet" than over rough ground. An efficient man shoveling backfill material, that is well broken up, into a trench not over 3 or 4 ft. wide or 6 or 8 ft. deep, will handle 20 to 25 cu. yd. in 10 hr.

Observations show that in backfilling average loam, clay and sand materials, one man will handle 9 shovelfuls per minute, or about 0.045 cu. yd. or 1.2 cu. ft. per minute. This is at the rate

Fig. 40. Drag Scraper Backfilling Trenches.

of 27 cu. yd. per 10-hr. day. However, interference with the work and periods of rest required by the men will reduce this daily output. On the other hand, if shovels larger than No. 2 or 3 are used, the output can be increased. With loosened earth and the short throw required in backfilling the shovels used for backfilling should be larger than those used for excavation.

In shallow trenches a team and scraper can drag the material directly into the cut. As a rule the scraper is operated on one side of the trench and the team on the other, the scraper being attached to the horses by a long rope or chain, and being pulled back by two men. Another method is to fill in narrow runways by hand across which a team can travel and to dump the earth

as close to the side of the runway as it is possible. Fig. 40 illustrates this method as used. This method cannot be practiced successfully with any but the steadiest of horses. The Doane and Lehr scrapers, both of which are built of hardwood sheathed with iron, are used for backfilling trenches. They are broad and wide and dump easily. Buck or fresno scrapers can be used for filling shallow trenches. A wing plow, with a deep and long mold board can be used where a neatly finished appearance is not necessary. The earth being piled close to the sides of the trench is thrown in by the plow as it is pulled through. The horses may be worked first on one side of the trench and then on the other, or they may straddle the trench if a long double tree is used. This is the cheapest method of backfilling. In sand and light clays the earth may be caved in with a hose and water. This method also leaves the trench with a bad appearance, and it should be trimmed off with scrapers.

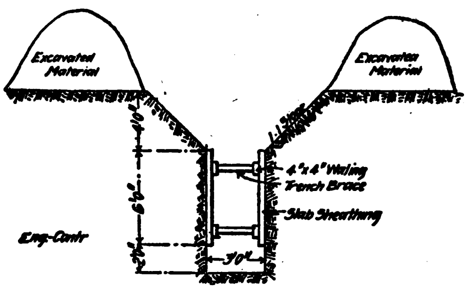


Fig. 1.

Fig. 41. Trench at Gary, Ind.

Fig. 41 illustrates a trench in sand at Gary, Indiana. The top 4 ft. of this trench were excavated with scrapers, and the remainder with hand shovels. *Engineering and Contracting*, Sept. 8, 1908, gives the following data relative to this work,

The sheeting was of slab wood cut in lengths of 4 and 6 ft. The lower 2 ft. of trench being free from sheeting permitted the pipe laying to be done much more easily. In backfilling the trench dirt was shoveled in over the pipe and up to the lower waling; then the sheeting was taken out and a water jet turned on the banks; this caused them to cave in, bringing down into the trench the excavated material piled on the sides. This was followed by a drag scraper that leveled up the ground. The cost of digging this trench was 12 ct. for shoveling per cu. yd., and 4½ ct. for shoring, making a total cost of 16½ ct. for excavating and

shoring, the pumping being extra. This is a low cost for excavating such a trench. The cost of backfilling was less than 4 ct. per cu. yd.

When a team with a drag scraper attached by a long rope is used, about 15 cu. yd. per hr. can be handled, provided the gang is efficient. A team and driver and two laborers, at $1.20 an hour, will thus scrape earth back into a trench for 8 ct. per cu. yd.

Ernest McCullough gives the following description of a method of using a hoisting engine and a scraper to refill trenches. The

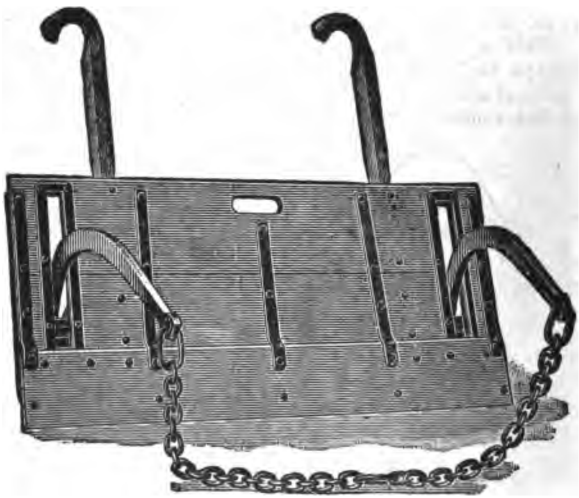


Fig. 42. Doane Scraper.

hoist is set at one end of the street and a cable is run alongside the trench to a pulley fastened to a tree (first wrapped with canvas or burlap to avoid chafing) or to posts. From this pulley the cable goes across the trench and is fastened to the scraper which is larger and heavier than an ordinary drag scraper, and has ropes fastened to the handles, by means of which two men haul it back and turn it over. This requires an engineman who does his own firing, a boy to signal him, and the two scraper holders. The total cost for labor, fuel, etc., is about $10 per day, which includes interest and depreciation. One hundred yards per day is all that can be figured on steadily on an average, so that the cost will be 10 ct. per yard. By adding two more

scraper holders and working the men in 10 or 15 min. shifts, as much as 225 cu. yd. have been put into a trench in 10 hr. It is almost necessary to have an old horse to pull the cable back when the men haul back the scraper, or else have a double cable and a tackle. When the horse is used the signal boy rides him. The increase in expense is not great and it lightens the work of the scraper holders.

Backfilling with a Keystone Traction Shovel equipped with a ditcher scoop has been successfully done by mounting a backfilling board on the scoop as shown in Fig. 43. In this way the scoop is converted into a power-operated drag scraper.

Fig. 43. Ditcher Scoop of Keystone Shovel Equipped with a Backfilling Board.

A Backfill Drifting Scraper. *Engineering and Contracting*, July 23, 1913, gives the following: This scraper, or so-called "go-devil," Fig. 44, was used for backfilling a trench on a 154-mile oil pipe line near Los Angeles, Cal. The machine was designed by James R. Kelly. The appliance was made of a share from a road grader and a handle was attached as shown. By means of chains of adjustable length the machine could be drawn by 4 horses. The labor required consisted of 1 driver and 1 guideman.

With this force about 5,000 ft. of trench, 3 ft. deep and 1.5 ft. wide, or 830 cu. yd. were backfilled per day of 9 hr., at a cost as follows:

4 head of stock, at $1.50	$ 6.00
1 driver	4.00
1 laborer	3.50
Total at 1.6 ct. per cu. yd.	$13.50

If an attempt was made to move too much dirt at one time great difficulty was encountered. Four to six rounds were usually necessary for backfilling a 3 or 4-ft. trench.

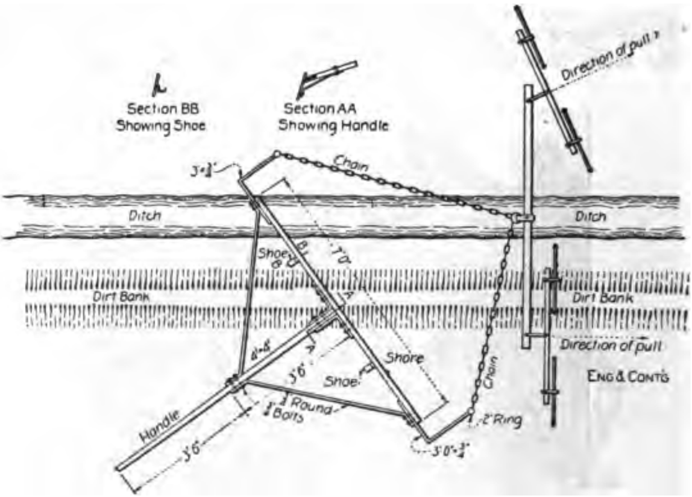


Fig. 44. Drifting Scraper for Backfilling Trench.

The Monahan Backfilling Machine. This is described in *Engineering and Contracting*, June 17, 1914.

Fig. 45 illustrates the Monahan backfilling machine in operation. This machine comprises a self-propelling 10-hp. engine and boiler with winding drums, and a bucket or scraper that slides on a frame transversely. This bucket has a hinged bottom or apron that is tilted in operation like a slip scraper in filling. The tilt of this apron governs the depth of spoil removed. This bucket holds about ½ cu. yd. and can make 15 strokes per minute on the average.

The Parsons Backfilling Scraper with Caterpillar Traction. This machine, Fig. 46, is described in *Engineering and Contracting*, Apr. 12, 1916. Its center of gravity is low. The cable pull is from the under side of the drum and is only 18 in. from the ground. Thus a great pull can be exerted without overturning

the machine. A 10-hp. gasoline engine is used, giving a speed of 95 ft. per min. on the backfill line and a pull of 3,500 lb. The scraper will work at the rate of four loads a minute. The weight in working order is 4,800 lb. This machine is made by the Parsons Co. of Newton, Iowa.

Cost with Austin Backfiller. According to Alvin C. Vogt in *Engineering and Contracting*, July 19, 1916, one of three backfilling machines made by the F. C. Austin Co. of Chicago, Ill., was used on sewer work in Norwood Park, Ill. The trenches were 24 in. to 36 in. wide in stiff clay, and the backfilling was heavy

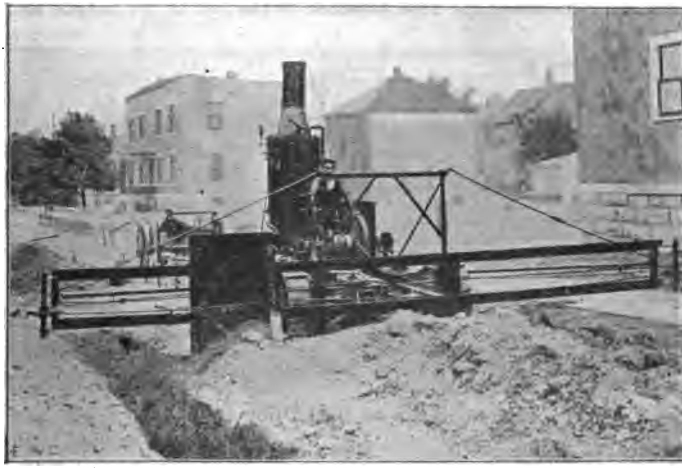


Fig. 45. Monahan Backfilling Machine in Operation.

work. The machine has a 10-hp. gasoline engine and is self-propelling. The operating cost was $10 per day and the average fill has been 600 ft. of 10 to 16-ft. trench per day. The machine referred to is similar to the Parsons backfiller, except that it has ordinary traction wheels instead of caterpillar treads.

The Waterloo Backfiller. *Engineering and Contracting*, Oct. 31, 1915, gives the following:

The Waterloo "Double-Quick" gasoline machine, illustrated in Fig. 47, is used in backfilling trenches; for light hoisting operations, hauling overground materials such a heavy timbers; loading, unloading and placing heavy pipe, valves, etc., in trenches; for cleaning sewers, and for pulling aerial and underground cables.

The machine probably finds its greatest field of usefulness in the backfilling of trenches. It has done this work at a cost as low as 2 ct. per cu. yd.

The essential elements of the machine are an engine and a winding drum; these are mounted on a turntable. This table swings easily and can be locked in any one of four position to permit the use of the winding drum from the front, rear or sides of the machine. At each setting of the turntable the scraper is readily operated through an arc of 90°. A dead-man is furnished with the machine and so also are 300 ft. of ⅝-in. manilla rope and a sheave. The machine moves along the trench under its own power by means of the rope attached to the end of the tongue and

Fig. 46. Parsons Backfilling Machine.

passing through the sheave on the dead-man and back to the winding drum. A ditching scraper also comes with the outfit. With the scraper is supplied 50 ft. of ⅜-in. steel cable which passes to the winding drum. The trucks are standard wagon gage and the wheels have wide tires. The total shipping weight is 2,630 lb. A 4½-hp. gasoline engine furnishes the power. The speed can be varied by a change of sprockets on the crankshaft of the engine. The scraper travels 150 ft. per minute in common soil and 100 ft. per minute in clay soil. Two men are required to operate the machine when backfilling; one holds the scraper and the other the single controlling lever.

The machine in operation possesses two incidental advantages of importance. It can be set on lawns or parking without damaging them when backfilling dirt piled on the side of the trench nearest the center of the street. In such cases teams cannot be

used for it is not permissible to drive them over the grass. The hoisting ability of the machine is utilized, also, in pulling out trench bracing which otherwise would have to be left in the trench.

The machine is built by the Waterloo Cement Machinery Corporation of Waterloo, Ia.

J. L. Bridges, in *Engineering and Contracting*, writes as follows: On Center and High Streets in Decorah, Iowa, about 1,500 ft. of ditch, 8 to 13½ ft. deep, 6 ft. wide at top (necessary be-

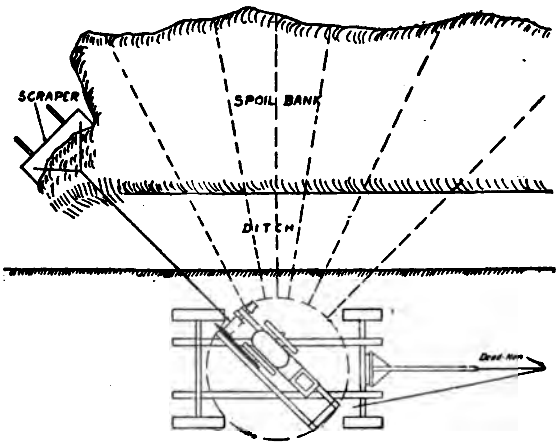


Fig. 47. Waterloo "Double Quick" Backfiller, Plan Showing Method of Operation.

cause blasting caused banks to cave) in nearly solid rock, were filled with the Waterloo filler and two men in six days' time. About 300 ft. of this ditch stood open from November to April, and I have never seen a team that could handle a scraper under these conditions. There has been considerable work in the alleys here and we have used this backfiller very successfully where it would have been impossible to use a team on account of the width of the alley, it being only 19 ft. between buildings. What I value the most is the fact that we have the filler on the job all the time, wasting no time waiting for a team, thereby keeping the ditches filled ahead of rain and keeping the streets open to traffic.

On straight, clean work, where there is plenty of room and enough to keep a team busy steadily, the cost of backfilling by

machine is approximately one-half of the cost of doing it by the team and scraper method. But on difficult work, and for short stretches where the team would not be available or would stand idle a part of the time, machine work costs from 10 to 40% of team or hand work.

At Decorah, Ia., we used four machines, following two Austin trenchers and five hand crews, the latter working largely in rock.

At Rockwell City, Ia., we laid 13,600 ft. of 4-in. water main in a 6-ft. trench in 13 working days, using two trench fillers, at a cost of 1 ct. per ft. for backfilling. The backfillers were hitched tandem following the trench machine.

Fig. 48. Flushing Trench; Tamped Walls at Intervals.

Puddling the Backfill. *Engineering and Contracting*, May 1, 1907, gives the following,

After the first foot of backfilling has been tamped with a light tamping stick, the remainder of the material should be shoveled in and should be tamped in 6-in. layers by not less than one tamper to each shoveler. If water is available the best method is to build hand tamped walls across the trench at intervals of about 25 ft., fill the space between the walls half full of water and then shovel the earth into the water.

A trench averaging 12½ ft. deep and containing a 48-in. main

was filled in the following manner: The trench was first filled with earth to within about 1 ft. of the top. An ordinary fire hose was then attached to a hydrant, the play pipe being about 20 in. long, with $1\frac{1}{8}$-in. nozzle. A 2-in. meter was attached which allowed only about 75 gallons of water a minute to go through the hose. The pipe was shoved down into the trench within 3 ft. of the bottom and the water turned in until the ground settled. The pipe was then pulled out and shoved down again. When the ground stopped settling and the water came to the surface, the operation would be started over again 4 ft. or 5 ft. away, zigzagging along the trench. After a sufficient quantity of water had been run into the trench it was evened off, the top material placed and rammed and the trench left fairly well crowned. The trench in this case was 7 ft. wide and after letting it stay for about a week, a steam roller was run over it. The street was said to have been left in as good condition as it was before the excavation was begun.

Tamping Clay. The following is from *Engineering and Contracting*, Aug. 11, 1909,

Clay containing a little moisture is ideal material in which to excavate trenches, but is extremely difficult to compact properly when refilling. As ordinarily placed back in the trench it occupies a much greater space than it did before being disturbed, and many wagon loads must be wasted. The clay placed in the trench always settles, sometimes occupying years in the process. Puddling is sometimes tried, but this method is only successful when the clay contains a large amount of sand. The best method of filling clay trenches is to place the loose material in thin layers around the pipes, tamping it carefully. Then put in loose material another foot deep. Pour in water until this material is barely covered. On this put enough material to hide the water and tamp it, adding dry material where soft spots appear, until the mass is firm. As long as mud appears the tamping is incomplete. Then deposit another foot of loose filling, cover with water and tamp as before. Repeat these operations until the trench is full. If the work is properly done it will be necessary to borrow some material to complete the filling.

The Cost of Backfilling and Tamping. *Engineering Record*, May 23, 1914, gives the following: The data were gathered by the Construction Service Co. Tamping was rigidly enforced. When water could be obtained sections of the trench were dammed at each end, the trench filled with water and the earth cast therein. For soils other than clay this is the most efficient method of compacting. The earth composing these dams was thoroughly tamped by hand. In one case water was used exclusively and the

cost of backfilling and puddling was 7.6 ct. (exclusive of the cost of water), wages being 15 ct. per hr.

Short time observations on work gave the speed of tamping with ordinary hand tampers as 60 strokes per minute or 1 stroke per second. If the face of the tamper covered a fresh place in

Fig. 49. View Showing Construction Tamping Machine.

the trench on each stroke and the material was tamped in 6-in. layers, then one man would tamp 220 cu. yd. per day. This is manifestly impossible. As a matter of fact, the tamper is dropped repeatedly on almost the same spot, and one man will compact about the same amount that another man will backfill, namely, about 20 cu. yd.

Where the material is stiff dry clay and compactness is insisted upon, the amount tamped will be very small. In *The Technic* of 1896 costs of tamping are given. From the data we have deduced the fact that when the material (clay) was rammed dry in 4-in. layers the amount rammed per man was only 1.1 to 2.8 cu. yd. per day.

The Stanley Tamping Machine. The Stanley power tamping machine is illustrated in Fig. 49. The description is taken from *Engineering and Contracting*, May 15, 1912. The tamper is lifted

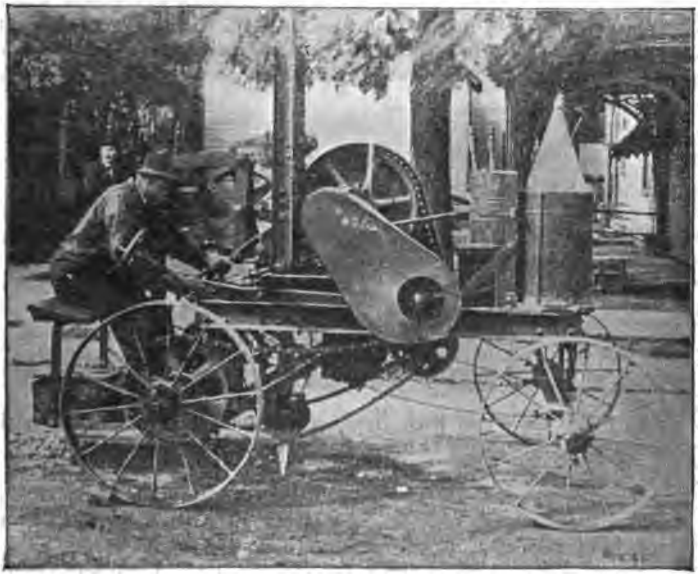


Fig. 50. A Pavement Picking and Trench Tamping Machine.

up and allowed to drop by a simple mechanism similar to that used on drop hammers in forge shops. The tamper moves automatically across the trench and the movement along the trench is attained by moving the machine forward about 8 in. As regularly equipped the machine will work in trenches 1 to 4.5 ft. wide and tamp at a depth as great as 6 ft., but can be furnished with a special arm enabling it to reach a depth of 16 ft. The machine requires a crew of 2 men and consumes about 1.5 gal. of gasoline in 10 hr. The manufacturer states that 1,200 to

1,500 sq. ft. per hr. can be tamped by the machine. If the material be compacted in 6-in. layers, and assuming that 50% of the time is lost, and that wages are $2 per day of 10 hr. and gasoline costs 15 ct. per gal., then 125 cu. yd. can be tamped per day at a cost of 5 ct. per cu. yd. The weight of the machine is 950 lb. and the cost (pre-war) is approximately $300.

The P. & H. Tamping Machine. *Engineering and Contracting,* Sept. 30, 1914, gives the following:

This machine, Fig. 50, was made for purpose of providing a rapid and economical means of cutting through pavements where trenches are to be opened and also to tamp backfilled material at a low cost. The interesting feature of the machine is the ease with which it may be converted for service on one type of work

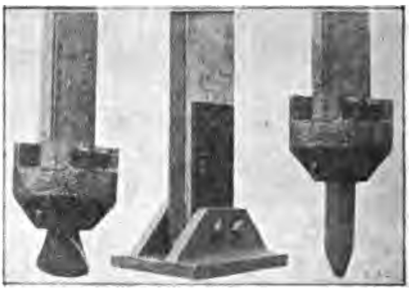


Fig. 51. Chisel and Pick Heads and Tamper Head for Use with Power Picking and Tamping Machine.

after use on another type. The only change necessary consists in substituting the pick or chisel point illustrated for the tamping head, also shown.

A recent test of this device by the Wisconsin Telephone Co. of Milwaukee was conducted as follows: The machine was equipped with the concrete breaking pick and was tried out in competition with a hand picking gang. The machine removed 372 sq. ft. of 6-in. concrete base in 410 min., an average of 0.91 sq. ft. a minute. By hand labor one man removed 23½ sq. ft. in 71 min., an average of 0.33 sq. ft. a minute.

On asphalt the machine cut 64 lin. ft. of groove in 26½ min., a rate of 72½ lin. ft. an hour, or in square yards of 36 in. wide trench, 16 sq. yd. per hour. Hand labor cut, in one case, 6 lin. ft. in 20 min., and in another 5 lin. ft. in 15 min., equivalent to 18 lin. ft. an hour or 2 sq. yd. of surface in the first case, and 20 lin. ft. or 2.22 sq. yd. an hour, in the second case.

The stroke of the tamping head is 22 in. (average), the total weight of head and ram is 150 lb., and about 45 strokes per minute are made. The head travels a distance of 20 in. across the trench, enabling it to cover a trench 32 in. wide. When in use on the trench the machine is fed forward at the rate of 6 to 15 ft. per minute, and when traveling on the road 1.33 miles per hour is the speed attained. This machine can tamp in trenches as wide as 40 in., and as deep as 7.5 ft. It is made by the Pawling and Harnischfeger Co. of Milwaukee, Wis.

Rolling Backfill. *Engineering News*, May 25, 1911, gives the following:

Rolling backfill is sometimes successful, provided the trenches are not too deep. Fig. 52 illustrates a concrete roller used for

Fig. 52. Concrete Trench Roller.

compacting telephone duct trenches. After the ducts had been laid, 6 in. of dirt was carefully filled in around them and tamped. Then the remaining dirt was backfilled in layers of 6 in., each layer being tamped and rolled by a small concrete roller.

On another section the earth was loosely backfilled and crowned about 6 in. above the roadway. Then a 10-ton steam roller was put on and the trench rolled. It is doubtful if this method of rolling the surface compacts the earth to a depth greater than a few inches or a foot.

Trench Tamping with Pneumatic Rammers. C. M. Hartley, in *Engineering and Contracting*, June 7, 1916, gives the following:

Where compressed air is available, the Crown floor rammers (type 22-SR), manufactured by the Ingersoll-Rand Co. of New York, may be used to good advantage. These machines, which consume 28 cu. ft. of free air per minute at a gage pressure of 100 lb. per sq. in., are easily operated by one man, who does not need to be a skilled laborer, and they do not require any great

amount of care to keep them in order, aside from cleaning and oiling.

Comparative tests of hand tamping and machine tamping have shown that the cost of the latter is about one-third the former, and, at the same time, the backfill is much better tamped.

We have backfilled a 50-ft. section of trench, 24 in. deep and 20 in. wide, containing 6.3 cu. yd., in one hour, with three men shoveling and six men hand tamping. This backfilling cost $1.80, or 28 ct. per cubic yard, and this ratio of tampers to shovelers insures good tamping. The hand tamping cost in this instance was 19 ct. per cu. yd.

Another 50-ft. section 27-in. deep and 20-in. wide, containing 7.1 cu. yd., was backfilled and machine tamped in one hour, four men shoveling and one man running the rammer. I have never seen earth filling better compacted than it is by these tampers. The cost of this backfilling was 18 ct. per cu. yd., and of the tamping alone, 6.9 ct. per cu. yd.

Other tests have verified these figures, and we have found that, as a rule, the cost of tamping with these pneumatic rammers, on this class of work, is about 7 ct. per cubic yard.

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CHAPTER XVII

DITCHES AND CANALS

Types of Ditches. The word ditch is here used to indicate a small artificial open channel for the passage of water. A "ditch" dug for the purpose of holding an earth covered pipe conduit should be called a trench.

The sides of ditches are sloped or so finished that they will withstand the action of water or the elements, while the sides of trenches have to be trimmed only enough to permit the use of sheeting or the entrance of the structure they are to contain. Large drainage and irrigation ditches are often called canals. Ditches, however, are channels with sufficient slope to discharge the waters they receive so rapidly that they will ordinarily be empty, whereas canals are channels of little slope whose slow rate of discharge makes them flow full continuously.

The classes of ditches commonly constructed are as follows:

Drainage Ditches are meant to carry water in the open ditch, for drainage purposes. When such ditches become wide and deep, they are no longer known as ditches, but are termed canals, although both in drainage and irrigation systems, all lateral canals are, as a rule, called ditches. Thus a ditch in one system may be of larger size than a canal in some other system.

Gopher Ditches are small underground channels made with special plows. Their construction is possible only in certain soils.

Irrigation Ditches. The remarks on drainage ditches are applicable to irrigation ditches. However, in irrigation work there are small ditches used between rows of trees and plants that tap the lateral ditches and carry water to the roots of the plants. Such ditches are made by hand or with a light turning plow, or some sort of scraper.

Double Levee Ditches are a special type of irrigation ditch used where the land is very flat. Parallel levees are built of material taken from both inside and outside of the proposed canal, and water is carried between these levees at a height sufficient to flood the adjoining land.

Roadbed Ditches. Ditches are excavated for drainage purposes in connection with both wagon roads and railroads. Small ditches are always made in cuts. For railroads these ditches are usually made 12 in. deep, 12 in. wide on the bottom and with 1 to 1 slope on the sides, making a ditch 3 ft. wide on top. This is for cuts through earth. Some engineers use the same size and kind for wagon roads, but as a ditch of this shape

has to be excavated by hand, the shape is changed on wagon roads so that they can be excavated by plows, scrapers, road machines or elevating graders. This is done by carrying the slope of the roadbed to meet a shoulder of the side of the cut, thus forming a V-shaped ditch.

Surface Ditches are excavated to prevent rain water from running into railroad or wagon-road cuts, or against embankments. These are generally small ditches, with the sides sloped, and are excavated by hand, the material from the ditch being thrown on the side of the ditch, between the ditch and the object it is to protect. Like roadbed ditches, these are paid for by the cubic yard of material excavated. These surface ditches are often termed berme ditches, but the author believes they should be called surface ditches in order to distinguish them from the ditches described in the next paragraph.

Berme Ditches. In building railroad and wagon-road embankments, the material is often obtained from ditches on each side of the embankment, leaving a berme from 4 to 10 ft. wide beteween the toe of the embankment and the ditch. This berme gives the ditch its name. These ditches are excavated by hand, by scrapers and with elevating graders.

Power Ditches are channels for carrying water from a dam or stream to a power generating plant or mill, and for taking the water away from the plant if it is not emptied directly into the stream. When used in connection with mills they are termed mill races, and the ditch carrying away the water is called the tail race. For electrical power generating plant the power ditch carries the water to a pressure pipe or penstock or a penstock pit. Such ditches are lined when it is necessary to prevent wasting water.

Military Trenches are really ditches, as they are not excavated with the intention of filling them in. They are excavated, and the earth thrown up on the side of the ditch towards the enemy to protect the soldier. The earth thrown up is known as a breastwork. For temporary purposes the ditch is made wide and deep enough to obtain enough earth, so that when it is piled up it will stop a bullet, the soldier lying down or kneeling behind the breastwork in the trench.

A Sap is a type of military trench, less used now than formerly, which is dug by specially trained soldiers in advancing against an enemy under fire. Saps are dug advancing toward the enemy in an inclined direction, and changes of direction are made at short intervals to avoid enfilade fire down the trench. The work is advanced without exposing the men to fire and in order that it may be done as rapidly as possible the advance man

works lying down and excavates a trench 15 in. deep ahead of himself. A second man works kneeling, and others follow who deepen and widen the trench until troops can pass through it comfortably.

Rifle Pits are small ditches, long enough to protect one or two men.

Reducing the Cost of Drainage Excavation. *Engineering Record*, Dec. 26, 1914, gives the following:

The reclamation of 488,000 acres of land in the Little River Drainage District in the southeastern part of Missouri involves the construction of many miles of flood-water diversion channels and impounding levees and 624 miles of open ditches for local drainage. These require a total excavation of about 42,800,000 cu. yd. of material. In general the material is excavated and deposited in final position at one operation by floating dredges, mainly of the dipper type, at an average contract price of 7.7 ct. per cu. yd., exclusive of the cost of clearing the land.

This work is located in a territory averaging 10 miles wide and 90 miles long, most of which is continually or frequently submerged and is covered with a heavy second growth of timber. There is a wide variation in the dimensions of the ditches and channels, which range in bottom width from 4 to 123 ft. and in depth up to 12 ft. Much of the work is too small for large dredges and too large for small ones to handle to the best advantage. Notwithstanding these conditions, prices satisfactory to the supervisors were obtained, chiefly through the method employed of classifying the work and arranging the contracts so that they could be handled advantageously and be adapted to continuous work by given units of plants. The fact that dipper dredges could be used for a large part of the excavation helped keep the cost down.

The diversion work, consisting of deep wide channels and high levees, involved 8,621,591 cu. yd. of estimated excavation. The bulk of it was divided into two nearly equal contracts. The local drainage work involved about 34,208,101 cu. yd. of estimated excavation and was divided into 27 contracts, awarded to 12 different bidders.

Governing Considerations. The classification and allotment of contracts was governed as much as possible by five principal considerations: (1) division of the work into units with channel dimensions particularly adapted to a standard type of machine, (2) allotment of sufficient yardage to each contract to give at least 2½ years' work to a suitable machine and thus make the contract attractive, (3) location of an accessible building site on some railroad at or near the head of each contract,

(4) provision for uninterrupted transportation of fuel to the excavating machines, and (5) elimination, as far as possible, of all upstream work.

The 2½-year duration of contracts was unobjectionable for the small work. On the large work, where the bottom widths range from 81 to 123 ft., there is required a 4½-yd. excavating bucket and a 100-ft. boom which, with its supplementary equipment, will cost from $40,000 to $75,000, and in order to reduce the cost per yard to reasonable limits an amount of work is required that necessitates the continuous operation of the plant for a long time. For these contracts this time was figured at three years, except in one instance where time limit was 40 months.

In classifying drainage bids there is great advantage in dividing the work into contracts before making the estimates of cost, because the combinations of different classes of work greatly modify their unit costs. For instance, a canal with a bottom width of 4 ft. may be 8-ct. work; but when such work is placed in the same contract with ditches having 25-ft bottom widths, the cost of the 4-ft. width may be much increased because the required width of a dredge suitable to excavate the 25-ft. canal will be much greater than that for the 4-ft. canal, and will necessitate considerable excess excavation.

Dressing the Sides of Ditches. The dressing up of the sides of ditches is done for an entirely different reason than in the case of trenches. As ditches are to remain open, there are few cases where the sides should not only be well dressed but also sloped.

The side slope is expressed as a ratio of horizontal to vertical measurement. Thus a "2 to 1 slope" has a vertical rise of 1 ft. in 2 ft. horizontal.

Ditches dug for irrigation, drainage and for power purposes should be made full size, and the banks should be sloped and dressed. A 1 to 1 slope is very commonly used, although this is varied from ½ to 1 to 2 to 1. Such slopes should be dressed up and trimmed, as the ditches can be kept clean easier.

For irrigation and other purposes it is frequently necessary to line ditches. Measurements of loss by seepage made on a large number of irrigation ditches in California, show an average loss on main canals of about 1% for each mile that water is carried. On laterals in some cases the loss amounted to 11 and 12% per mile. At times the loss has exceeded 50%.

In gravelly soil the loss is always excessive, and the water so lost from irrigation ditches and canals is more than wasted, as this water collects on lower lands, filling the soil and souring it, drowning the roots of trees and plants, and when it collects in pools, furnishing a place for the breeding of mosquitoes. The

reader is referred to *Engineering and Contracting*, Dec. 2, 1908, for seepage data.

The lining of ditches, besides preventing loss by seepage, accomplishes three other purposes. First, the ditch can be kept clean easier. The smooth lining does not impede the suspended matter as readily as does an unlined ditch, nor do weeds and grass grow in the ditch to become a deposit of decayed vegetable matter. The actual work of cleaning out the ditch is also easier.

If a ditch is not lined, the edge of the ditch, even if it is made a straight line when constructed, soon becomes uneven and grown up with weeds and brush. This impedes the flow of water.

The third effect of a lined ditch is to prevent the water from

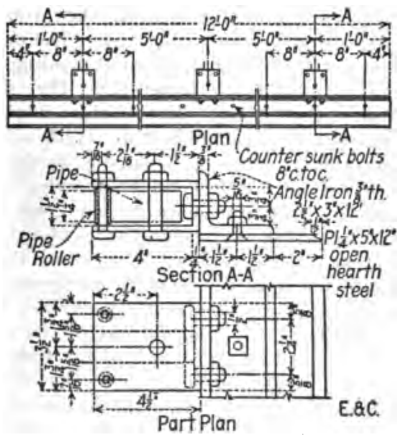

Fig. 1. Details of Slope Trimmer.

washing the ditch deeper and scouring its sides or banks. Not only does the water in the ditch do this, but rain water falling on or near the banks washes them badly. However, a cheap lining will often prevent this as well as a more expensive kind. A dry stone paving, or even crushed stone spread over the bottom and sides of the ditch will serve for this purpose.

An Irrigation Canal Slope Trimmer. *Engineering and Contracting*, May 3, 1916, gives the following:

The device, Fig. 1, is a three-handled push knife 12 ft. long. The handles are 1¼-in. pipe. The practice is to set to exact slope down the bank and 10 ft. apart 1¼-in. T girders. The trimmer is set on these tee tracks at the top of the slope and

pushed by the handles down slope, thus shaving the earth to an exact plane between the tees or girders. This trimmer showed considerable saving in labor compared with men using shovels. It was designed by U. S. Reclamation Service Engineers of the Carlsbad Project.

Hand Excavation. The appliances described in Chapter XVI are meant for trench work, but some of them are also adapted to ditch construction.

In sand, ditches can be dug entirely with a shovel. For this purpose a long handle shovel should be used with a large squire blade. Faster and cheaper work can be done by wetting the sand, whenever it is possible to do so, before the material is excavated, as much larger shovelfuls can be handled.

In digging ditches for drainage work the ground is always wet and frequently is saturated with water. The ordinary shovel for such work is not a good tool as more spading is done than shoveling. Hence a spade is preferable. The short handled spade is in common use, though more efficient work can be done in many cases with a long handled tool. With a solid blade in wet material the spade is difficult to handle, as the suction on it causes either very slow work or else breaks the tool. For this reason, the skeleton blade for a spade has come into common use, as with it this suction does not occur; and not only is rapid work done, but there is little chance of breaking the spade. The blade is also made much longer than the ordinary shovel blade, so that it is possible to dig a narrow and shallow trench, except the finishing, with this spade at one stroke of the tool.

With a spade in soft materials a pick or mattock is not needed, as both the shoveling and digging are done with the spade. In wet plastic material the pick is of little use; a mattock does better work. A mattock is also needed where roots or old stumps are encountered. It is also used to trim the sides of open ditches, which should always be given good smooth slopes.

Spading Wet Soil. When ditching in wet ground, filled with grass roots, making hard spading, L. Z. Jones, in the transactions of the Illinois Society of Engineers and Surveyors, 1903, says that a narrow bladed hay knife should first be used, pushing it as deep as possible along each side of the trench. This cuts the roots so that each spadeful has one side free. A three cornered piece of earth should then be spaded out, the spade being turned right and left alternately. This makes easy digging. A flat spade should not be used, for it will not hold sufficient earth. Use a long-handled round point mining shovel with an air hole in the middle to facilitate the removal of wet soil, and a long or short ditching spade according to the depth of cut. In tough

clays nothing equals the three-tined skeleton spade, as this enters easily and is self-cleaning. To remove the loose earth from the bottom of the ditch use a tile scoop or cleaner. One can be made from an old scoop shovel by bending it like a sun-bonnet, and riveting on a bent shank so that the scoop will hang like a hoe. Fasten the shank to the large end of a buggy shaft and put a D-handle on the small end of the shaft. Have all tools very sharp.

Special Ditching Machines. Although every type of equipment is used with success in digging ditches the following classes of machinery are specially adapted to this sort of excavation:

Fig. 2. Buckeye Traction Ditcher for Open Ditches.

Wheel Excavators. These are similar to the trenching machines described in the last chapter except that instead of having their excavating buckets fixed on a chain they carry them attached to a wheel, like spokes. The buckets move in the line of the ditch.

Template Ditch Excavators. These excavate by means of buckets moving across the line of the ditch.

Land Dredges of the drag line and steam shovel types specially mounted for ditch work.

Capstan Plows. These are heavy plows drawn by cables.

Buckeye Excavator for Open Ditches. Fig. 2 shows this machine. Two men are required to operate the machine, besides one

man with horse and wagon to haul fuel and water. For a 12-ton machine only 800 lb. of coal are needed per 10-hr. day.

With this plant and crew a ditch 3½ ft. deep, 2 ft. bottom, and 4½ ft. top was excavated at the rate of 5 lin. ft. per min., working in wet and very soft ground at Raceland, Louisiana.

The ditcher is self-propelling and can be used for draining swampy lands, for cleaning out old ditches, and for digging the side ditches for roads.

Cost of Operating Wheel Type Excavators in Drainage Ditching. D. L. Yarnell in *Engineering and Contracting,* June 26, 1916, gives the following:

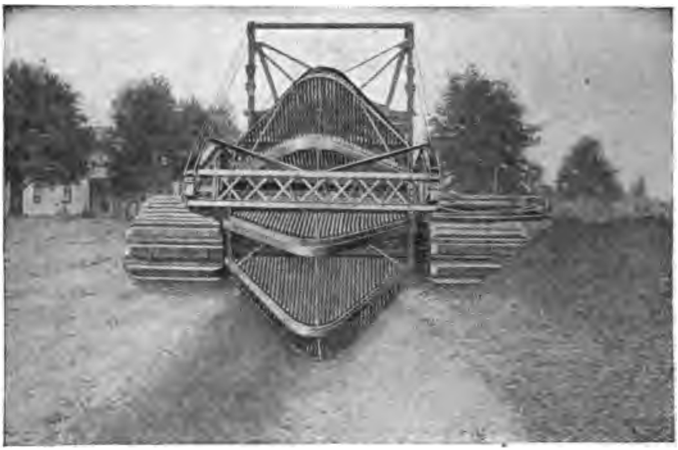

Fig. 3. Rear View of Ditcher.

Two machines of the wheel type designed to cut a ditch 4 ft. deep, 4 ft. wide at the top, and 2 ft. wide at the bottom, were used on the excavation of some ditches in one of the Gulf States. Each machine was driven by a 28-hp. gasoline engine. The digging wheel was 15 ft. in diameter and the two apron tractors each 5 ft. by 12 ft. The weight of each excavator was about 30 tons. The first cost of the machine was $5,500 and freight to the point of use was $338, making the total cost of each machine $5,838. The soil was a hard, yellow, sandy clay overlain by a turfy muck, varying in depth up to 2½ ft. The turf was easily cut, but the hard clay caused excessive wearing on the bearings. A large part of the work was done when water

was from 2 to 3 ft. deep on the land. The total length of the ditches dug was 165 miles, the average length of ditch being 2,475 ft. The average depth of digging was about 4 ft., with a 4-ft. top and 2-ft. bottom. The average distance dug per shift of 10 hr. of actual running time was 2,250 ft.; the maximum distance dug in 10 hr. was 6,600 ft. The average yardages per month for the two machines were 13,245 and 13,180 cu. yd., respectively. The average daily outputs on the basis of the actual running time

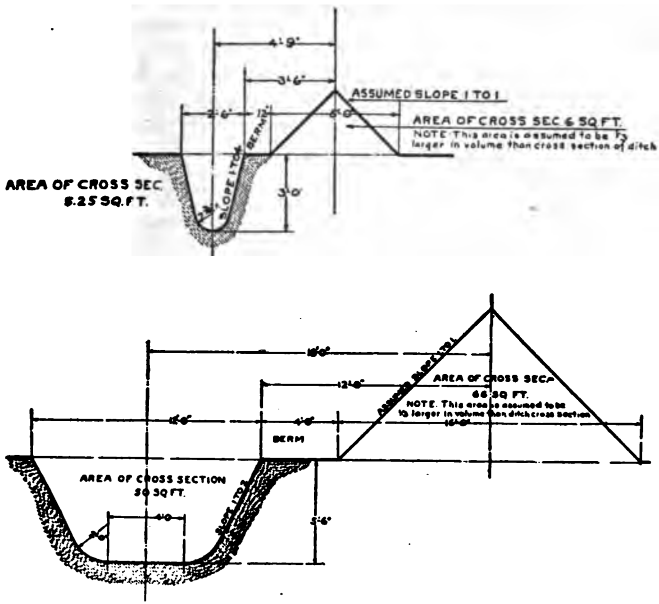

Fig. 4. Large and Small Ditch Sections Possible with the Same Machine.

were 1,000 and 1,126 cu. yd., respectively. A part of the time the first machine ran a double shift, which accounts for the higher monthly and less daily average. It required 13 months to complete the work, the actual time of operation being about half this. On account of the excessive wearing on the bearings, caused by the heavy sandy clay, it was necessary to make frequent stops for rebuilding the machines, which operation occupied an average of nearly two weeks. The total excavation was 317,162 cu. yd.

The daily operating expense per 10-hr. shift for each machine was about as follows:

One operator, at $100 per month	$ 4.00
One assistant	2.00
50 gallons gasoline, at 16 ct.	8.00
Repairs	6.00
Other charges	12.00
Total per day	$32.00

The itemized cost for operation for the entire work was as follows:

Labor	$ 5,172.11
Interest, discount, and exchange	202.05
Maintenance and repairs	2,860.08
General expense	273.10
Management expense	1,600.00
Provisions and cooking (cook's wages)	2,245.91
Freight and express	75.74
Towing	458.19
Gasoline	1,792.22
Other oil	281.49
Teams and livery	932.11
Telephone and telegraph	25.29
Motor boat operation	540.96
Interest and depreciation on machinery	5,185.00
Total at 6.82 ct. per cu. yd.	$21,644.25

	Machine No. 1.	Machine No. 2.
Running machine	$ 917.97	$1,509.66
Repairing machine	1,431.37	771.96
Moving machine	105.20	88.51
Machine bogged	156.90	190.54
Total	$2,611.44	$2,560.67

The excessive cost of labor given for the machines when bogged was due to the frequent crossings of a wide, muck-filled bayou which ran the entire length of the district. This bayou was about 1,500 ft. wide; the muck ranged from 5 to 15 ft. and was very soft. No tree roots, submerged timber, or stumps were encountered. The work covered an area of about 7,000 acres, approximately square, which was traversed by parallel canals every half mile. The ditches cut by the excavators were at right angles to these canals and were spaced 330 ft. apart. It was thus necessary to turn the machine around and run it light 330 ft. for each half mile of ditch cut. The item "moving" is for taking the machine across the canals and for moving from one part of the district to another; it does not refer to the moving between adjacent ditches.

Another machine worked on comparatively solid ground. Power was supplied by a 28-hp. gasoline engine. The first cost was

$4,000, and freight charges from factory to works were $350. After the machine had been operated for a short time it became apparent that the excavating wheel was far too light and a new wheel was substituted. The soil was a silt loam, firm and uniform but not tenacious. No special difficulties due to soil conditions were encountered in this work. The chief obstacles to rapid progress were at first the weakness of the light excavating wheel, and afterwards the extra-heavy excavating wheel which unbalanced the machine. The tractors were larger than necessary and often broke down when turning on the hard ground. At the time the following cost records terminated, the work had been carried on intermittently for about 18 months; about one-half this time was occupied in repairs. During this time the machines dug 117,000 ft. of ditch 4½ ft. deep, 45,500 ft. 3½ ft. deep, and 9,250 ft. twice over, the machine making two 4½-ft. cuts side by side. The average length of ditch cut per day was 800 ft., while the maximum was 1,950 ft. The daily cost of operation was as follows:

Labor	$ 5.50
Fuel	4.20
Incidentals	0.50
Repairs	2.40
Total per day	$12.00

The average excavation per day was 410 cu. yd., based on the average of 800 ft. of ditch, 4½ ft. deep, 4½ ft. wide at the top, and 20 in. wide at the bottom. The machine excavated 82,330 cu. yd. in 18 months at the following itemized cost:

Gasoline based on 215 actual days' operation	$ 903.00
Repairs, actual cost	860.00
Incidentals at 50 ct. per day	120.25
Labor of foreman, 18 months, at $75 per month	1,350.00
Other labor, two men, $2.50 per day for 250 days	625.00
Interest and depreciation	2,675.25
Total at 7.93 ct. per cu. yd.	$6,533.50

Low Costs of Ditching in the Everglades. W. J. Kackley in *Engineering Record*, 1914, gives the following:

Fig. 5 shows a ditcher which is now operating on the property of the Everglades Sugar & Land Company in Dade County, Florida. This machine was built by the Buckeye Traction Ditcher Company, of Findlay, Ohio, but was completely remodeled by our forces to meet the conditions as found in the Everglades. The machine weighs 37 tons and is equipped with a 45-hp. gasoline engine. The bearing on the ground is approximately 350 lb. per sq. ft.

Living quarters are provided for the crew on top of the machine. This house will accommodate eight men. An independent electric generator furnishes light for the living quarters and for a searchlight, which makes it possible to run at night. The machine cuts a ditch 9 ft. wide on top, 2½ ft. wide at the bottom and 5 ft. deep at an average rate in sand and muck of 8 ft. per min., or 480 cu. yd. per hr. It has cut 1 mile of ditch in 10 hr., or 528 cu. yd. per hr. Our records for December, 1913, show a total of 43,630 cu. yd. of material excavated at a cost of 2.9 ct. per cu. yd., including overhead expense, fixed charges on the machine and cost of clearing line. Some exceptionally

Fig. 5. Ditching Machine with Quarters for Eight Men Used in the Florida Everglades.

hard sand cutting and heavy clearing were encountered during the month.

From Jan. 1 to Jan. 23, the machine has excavated 58,630 cu. yd. of sand and muck at a total cost of 2.4 ct. per cu. yd. Owing to the fact that the muck soil is too soft and spongy to permit of transportation by animals, the machine must carry supplies for an 8-mile run, 4 miles out from the canal and back, cutting in both directions on lines ¼ mile apart.

The Stockton Ditcher. This machine, Fig. 6, is unique in that it can excavate and widen a ditch by taking off successive slices. This enables the machine to be used for digging trenches or wide canals or for stripping areas. The limit of the width that can

be removed depends upon the length of the belt conveyor, as the spoil bank will eventually interfere with the operation of the machine. The machine is fitted with caterpillar traction enabling it to travel over very soft ground or to span a ditch 6 ft. wide. Fig. 6 shows the machine widening a ditch in soft peat soil.

The machine is manufactured by the Stockton Ditcher Co., Stockton, Calif.

Fig. 6. Stockton Ditcher Widening a Ditch in Soft Peat Soil.

The Austin Template Excavator. The distinguishing feature of this machine (Fig. 7) is that it is designed to cut a ditch true to grade having banks sloped to any desired angle, with the spoil bank at a sufficient distance from the ditch to prevent the banks from caving.

This machine constructs a ditch of practically any depth, width of top or width of bottom desired, and slopes the sides to any angle at a single operation. The waste banks are also constructed at a distance from the ditch, and it is possible to make them serve as continuous dikes, in this way increasing the capacity of the ditch during times of flood. The machinery is run on temporary rails, laid one on each side of the ditch. The machine can operate either up grade or down. The work can be done whether there is water in the ditch or not. An advantage claimed

Fig. 7. Ditch with 8-ft. Bottom, 1½ to 1 Slopes, and 10-ft. Deep, Dug by Type A Austin Machine.

for this machine is that being carried on a track, it travels in a straight line, making a perfectly straight ditch.

A frame work upon which the digging buckets operate is made to conform to the shape and size of the ditch, thus acting as a template for shaping the ditch as it is being excavated. A berm from 10 to 15 ft. wide is left between the top of the slope of the ditch and the spoil bank.

The excavating buckets, two in number, are mounted on wheels, and they cut in opposite directions, one always being in readiness to dig while the other is dumping its load. The guiding frame is fed down automatically to any depth desired within the capacity of the machine and is under control of the operator.

The guiding frame can be elevated above the surface of the ground and the excavator can thus be carried across the country under its own steam on a temporary track. So rigged, it can be moved a mile a day. The machine is made of steel. It can be run on rails, mounted on a walking device, or on a pontoon or boat, but its best work is done when operated on rails. It takes four men to handle this excavator. An engineman, a fireman and two men to care for the track.

This machine is made by the F. C. Austin Co. of Chicago.

The Judkin Ditcher. This machine (Fig. 8) is a dry land excavator consisting of a car which runs on rails, one being laid on each side of the trench. A steel frame extends under the machine and over it. On this frame in front is an endless chain carrying a series of plows. At the rear of the frame are two belts running in opposite directions. The endless chain runs transversely to the direction of the ditch, being controlled by pulleys, so the lower half of the frame will conform to the cross section of the ditch. The general method of operating this machine is similar to that of the Austin, the ditch being cut in sections, the frame being raised up to the surface after a section is excavated, and work started on a new section.

"At the back of the car, transversely to the direction of the ditch, is a triangular shaped cutting frame, the lower part of which is constructed to conform to the bottom and slopes of the proposed ditch. Over each half of this frame are two chain belts, 30 in. apart, and between these belts are riveted at equal distances 14 buckets, which excavate and carry the material. The cutting edge of these buckets can be detached from the main part for sharpening if occasion requires. The buckets over each half of the frame travel in opposite directions, so that each set passes up the slope of the ditch where it does the excavation. Their direction is changed at the apex of the triangle by

sheaves, each bucket making a complete revolution every 45 seconds, although in easy digging they can be run at a speed of two revolutions per minute. The excavating frame can be put together in such a manner that it will cut a narrow or wide bottom, or a different slope. The excavated material is cut up very fine and deposited on either bank. The spoil banks have uniform slopes coming to a sharp edge at the top.

"Strips 30 in. wide are excavated at a time, and after the machine has made an advance of 30 ft. it goes back over the ditch to clean up the loose material and the slopes. Then it goes

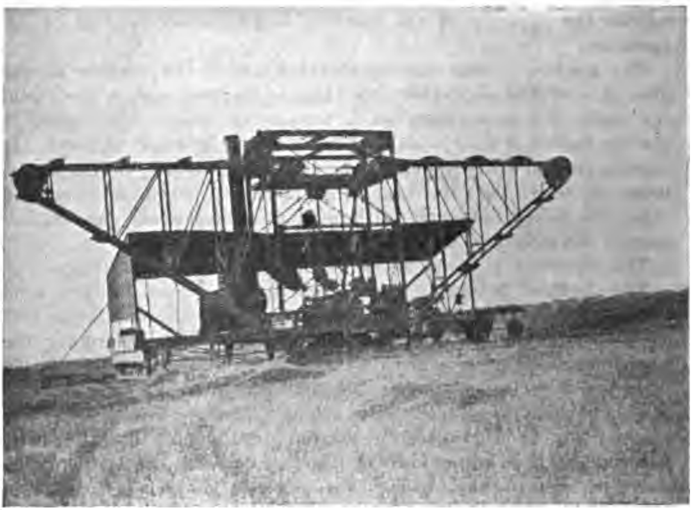

Fig. 8. The Judkin Ditcher.

ahead once more. In the center of the ditch there is left a small ridge of earth, caused by the excavating buckets crossing. This can be shoveled out by hand or the water will wash it away, extra earth being taken from the bottom to allow the material in the ridge to bring the bottom back to grade. The entire machine is under one man, but he has a fireman, an oiler, a man and team for hauling water and 4 men and team for moving track, which is laid in 30 ft. sections." The description of this machine is taken from a bulletin of the Northeastern Experiment Farm of the University of Minnesota, where one of them used at Bowesmont, N. D., is described.

An average of two tons of coal for a day's run of 14 hr. is required. This machine, in a 33 days' run of 14 hr. per day, made an average of 1,449 yd. per day, or a little over 100 cu. yd. per working hr. The machine has a total weight of 60 tons, will cut a bottom 7 to 10 ft. in width with side slopes 1½ to 1.

Ditch Excavation with Templet Excavators. D. L. Yarnall, in *Engineering and Contracting*, Feb. 9, 1916, gives the following:

A single-bucket templet excavator was used in southern Louisiana on the construction of 7,825 ft. of ditch having a 24-ft. bottom width and ranging in depth from 3.5 to 7 ft. The side slopes were 1 to 1, and the width of berm was 15 ft. The total excavation was 43,128 cu. yd. The total cost of this machine on the work was $8,506. The soil was a yellow clay with a few spots of gravelly clay, and the top soil was baked very hard. No special difficulties were encountered except that considerable cribbing was necessary to level up the track supporting the excavator when crossing natural water courses. Except for these streams the ground was level. Some trouble was also experienced with the traction device, due to the fact that the ditch was larger than that for which the machine was designed. The actual number of working days was 128 days, of which 73 were spent in actual digging. The cost of operation per day was as follows: One operator, $3.85; one fireman, $2.28; three deck hands, $6.27; one team and teamster, $5.40. Total per day, $17.80. The average daily excavation for the number of days worked was 107 ft. of ditch or 337 cu. yd. The total cost of operation for 5 months was $3,500. Interest and depreciation in that time, at 41% per annum, would amount to $1,452, making the total cost $4,953 and the cost per cubic yard 11.5 ct.

The operating cost was distributed thus:

Labor, operating	$1,885.25
Labor, repairs	294.48
Material, operating	496.03
Material, repairs	222.99
Fuel	601.84
Total operating cost at 8.1 ct. per cu. yd.	$3,500.58

Land Dredges. These machines may be divided into two types: (1) Those moved on wheels or caterpillar traction, or travelling on rollers, and (2) walking dredges. The term includes almost any kind of locomotive crane or travelling derrick operating a dipper or bucket, and used for the excavation of ditches. The disadvantage of the land dredge, as compared with the floating dredge, is that it is impossible to use one in excessively soft ground. Platform traction wheels, however, will enable a dredge

to travel on moderately soft ground. The chief advantage of the land dredge is that with one of these machines it is possible to begin digging a ditch at any point. With a floating dredge, excavation is usually begun at the head of the ditch in order that there may be sufficient water to float the hull. If work is abandoned at any time that part of the ditch already dug is in most cases useless. In fact, it may be a detriment, for an unusual flood would carry a large volume of water to the point where the ditch ended and possible cause considerable destruction to property. The land dredge can start work at the outlet of a

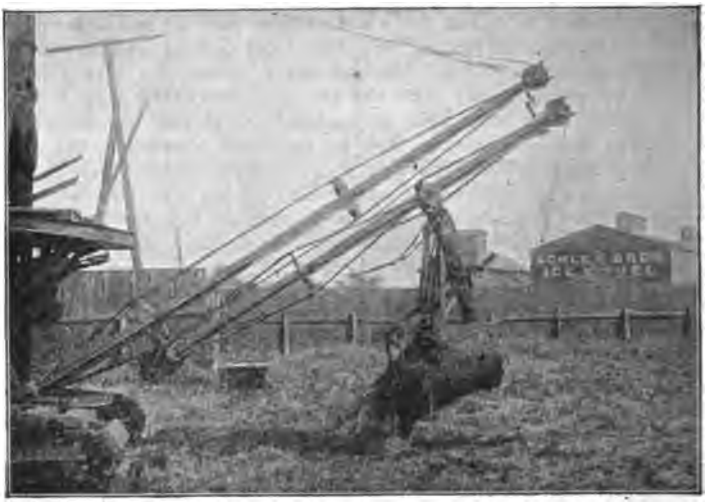

Fig. 9. Gopher Traction Ditcher.

ditch, and, as far as dug, the ditch becomes a useful work, draining the land through which it flows.

The Gopher or Straddle Ditcher. This machine (Fig. 9) is built by Mayer Brothers, Inc., Mankato, Minn. The machine is mounted on two steel beams that straddle the ditch the machine digs. The four outer ends of these beams are each provided with a two-wheeled oscillating truck. The wheels are 2 ft. high and 18 in. wide. They run on plank track 6 in. thick, 3 ft. wide in six sections, each 20 ft. long. One section on each side is always loose and the sections are moved forward by two special cranes with which the machine is provided for this and

other purposes. The planks are wide enough to hold the machine up on the softest ground and slough. The dredge will dig 12 ft. deep and 22 ft. wide on firm ground. It will deposit the dirt 32 ft. out from the center of the ditch to the center of the bank to either side, making it 64 ft. from center to center of said bank. The dipper will swing free over a bank 14 ft. high.

The machine is pulled ahead with a cable from the engine hooked to the track from both sides, and run to a dead man ahead of the dredge. The moving is done without interfering with, or stopping the work of digging. The total weight of the dredge is about 25 tons, and it is equipped with a dipper having a capacity of one cu. yd. It is stated that the dredge will excavate from 500 to 800 cu. yd. of earth in 10 hr. This machine is meant to operate either in dry material or where there is water in the ditch.

The King Ditcher. Another type of dipper machine is known as the King Ditcher, manufactured by the Marion Steam Shovel Co., of Marion, Ohio. This machine is for dry land excavating. However, water will do no harm unless it is high enough to interfere with the working of the machinery.

The boiler, engines and boom are all mounted on a large drag or mud boat. As the hull is comparatively narrow, easily adjustible jackarms are placed on each side of the machine to prevent it from tipping. It is provided with a pair of independent cable drums with cables attached to anchors placed in the ground on each side of the ditch. By this means it is propelled along the ditch as fast as the material is thrown out. It can be used on any kind of work, from soft material to the hardest clay or hardpan, and material may be dumped into cars or carts, or deposited on the banks as required. The material is dug with a regular steam shovel or dredge dipper.

This ditcher is adapted for excavating lateral ditches, where there is not sufficient water to float a dredge, or narrow trenches or ditches where little or no slopes are needed. For large ditches, especially, with water in them the Marion Steam Shovel Co. makes floating dredges of various sizes and capacities. They also mount some of these dredges with dipper capacities from 1¼ to 2½ cu. yd. and with booms from 35 to 70 ft. long, on wheels. These are known as Traction Dredges. Under each corner of the dredge is placed a small four-wheeled car or truck, and these cars run on two rails or a track laid down for that purpose. By means of cables the dredge is propelled. The platform or hull is of such width as to make the use of bank spuds or jack screws unnecessary.

The Fairbanks Walking Dredge. *Engineering News*, Apr. 26,

1911, describes a ditching machine (Fig. 10) that is made by the Fairbanks Steam Shovel Co., of Marion, O., and is known as a "walking dredge." This machine is designed to excavate ditches where it is impossible to get enough water to float an ordinary boat. It does not require any track or rollers to move it ahead. The machinery is placed on a timber hull or platform well braced, to go over the constructed ditch and the boom is operated like that of an ordinary dredge by a turntable. The shovel, which is the digging part of the machine, is shaped very much like a slip or drag scraper. It has a capacity of from

Fig. 10. View of Walking Dredge for Dry Ditching.

one to two yards. It is attached to a long arm, which is let down to the ground and the shovel is filled by means of a drag line from the engine. The shovel has two tails and two lines on it. The second tail keeps the shovel in an upright position as it is being loaded, and by releasing the line the load is dumped.

A somewhat similar machine to this and also called a walking dredge, has been used in Minnesota on ditch work. This machine has a second boom, known as the walking beam, suspended from the boom. Pivoted on the end of the walking beam is the shovel arm, and the shovel or scraper instead of working toward the machine as in the Fairbanks dredge, when loading works away from it. This is accomplished by pulling with a

chain on the upper end of the shovel arm. The load is released by a pull on a chain attached to the bottom of the shovel arm.

"The peculiarity of this machine is the method of moving. Under each corner is a timber platform the shape of a stone boat, called a foot (Fig. 11). Each of these corner feet is 6 ft. wide, 8 ft. long and 4 in. thick. They are joined together transversely by a light timber. This requires them both to

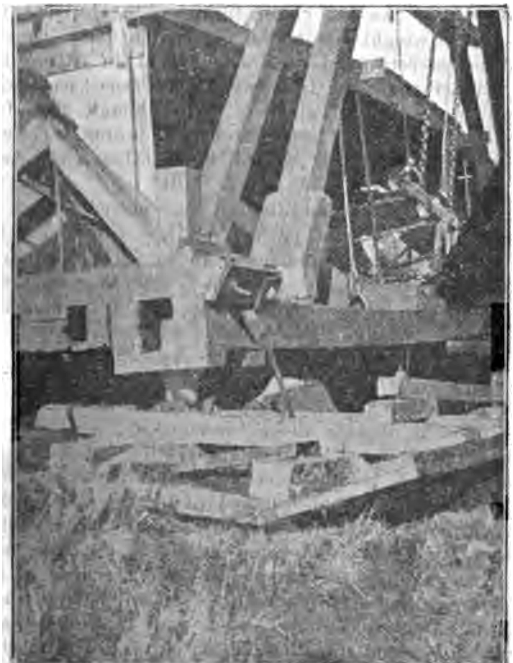

Fig. 11. Corner Foot of Walking Dredge.

move in the same direction, the direction being controlled by a chain which runs from each corner foot to a drum that is operated by the craneman. Near the outside of each corner foot there is a knife made of iron, one-half inch thick by 6 in. wide and 6 ft. long, which prevents the foot slipping sidewise. Midway of the machine on either side is a center foot 6 ft. wide, 14 ft. long, 6 in. thick. On the under side a 6 x 6 in. timber

is bolted crosswise, to prevent slipping back. This foot is attached to a heavy triangle frame, free to move longitudinally between the double side frame of the hull. A chain, the end of which is attached to the side timbers of the hull, passes over two pulleys in this triangular frame and then passes along the hull to the back corner and across the back end to a drum which is located about the center of the hull. When it is desired to move the machine the power is turned on to this drum and the chain wound up. As the chain tightens, the hull of the machine rises, the weight coming on the center foot. The winding on the drum is continued until the weight in lifting the hull becomes greater than the friction at the corner feet, when the entire hull moves ahead about 6 ft., although an 8-ft. move can be made. The chain is then released, taking the weight off the center foot, which is pulled by another chain attached to a drum in the front part of the hull.

"This machine, when not digging, has moved across country at the rate of one mile in 11 hr. While working, the machine threw 7 shovels of dirt and moved ahead 6 ft. 8 in. in 7 min. It worked at this rate several times and this seemed to be about an average speed. Short bends cannot be made, as the feet are liable to slip into the ditch and wet caving material causes trouble. When the banks are dry and firm there is no difficulty in moving."

The Monighan Walking Excavator. An excavator which is mounted upon a tractor device having a "walking" motion instead of being mounted upon rollers or wheels, has been brought out recently and is used especially in land drainage work. The advantages claimed for this method of moving the machine are in giving a much larger bearing area than rollers, wheels, or caterpillars; and in giving only a direct pressure upon the ground, thus avoiding the tearing up and churning of soft soil by wheels or caterpillars. It requires no tracks for wheels and no skids or plankways for rollers, and thus dispenses with men required to handle such auxiliary parts. The machine can travel in any direction and can change its direction readily, turning angles or curves without any skidding. The mechanism for moving comprises few parts, which are large and substantial and not liable to wear.

The excavator is of the drag-line type and is shown at work in Fig. 12, while Fig. 13 shows the details of the tractor or traveling device. The steel frame carrying the machinery and boom revolves upon a turntable or circular base which rests on the ground and forms the support of the machine when working. The bottom of this base frame is covered with steel plates,

so that it provides a large bearing area. Across the upper or revolving frame extends a 9-in. shaft carrying at each end a cast-steel sector *A*, to which is pivoted a lifting beam *B*. From this beam is suspended the shoe or platform *C*, which has a steel frame shod with plank. Upon the shaft is a large spur wheel *D*, gearing with a pinion which is mounted on the shaft of the loading drum and is fitted with a jaw clutch and a band brake.

When the machine is excavating, there is no load upon the shoes, which are swung clear of the ground, the entire weight being carried by the base of the turntable. When the machine is to be moved, the pinion clutch is thrown in and the engine

Fig. 12. Monighan Walking Excavator. When working, the weight is carried by the solid-base turntable frame A. When moving, the weight is carried by the two shoes B B.

started, thus driving the cross-shaft. As this revolves, the sectors and beams lift the side shoes and swing them 8 ft. forward, till they rest upon the ground. The continued revolution of the shaft causes the sectors to ride or rock upon steel plates on top of the shoes, the entire weight of the machine being thus transmitted to these shoes while the machine is lifted bodily and shifted 8 ft. forward. The total advance is thus 16 ft. When the movement is completed, the sectors lift the shoes clear of the ground, and the machine is again carried upon the broad base of the turntable. The clutch is then released, and the machine resumes work.

As the shoes are carried by the revolving frame, there is no skidding in turning the machine at an angle or curve. With

the shoes raised clear of the ground, the machine is revolved into the desired line of direction, the shoes being then lowered and the machine advanced in this line. Thus it is readily movable in any direction, and wide ditch work can be handled with a comparatively short boom, the machine working alternately on opposite sides of the center line of the cut. The shorter boom permits of a larger bucket and greater excavating capacity. As the shoes are raised about 2 ft. from the ground, it is easy to place timbers or earth filling beneath them if required in very soft ground.

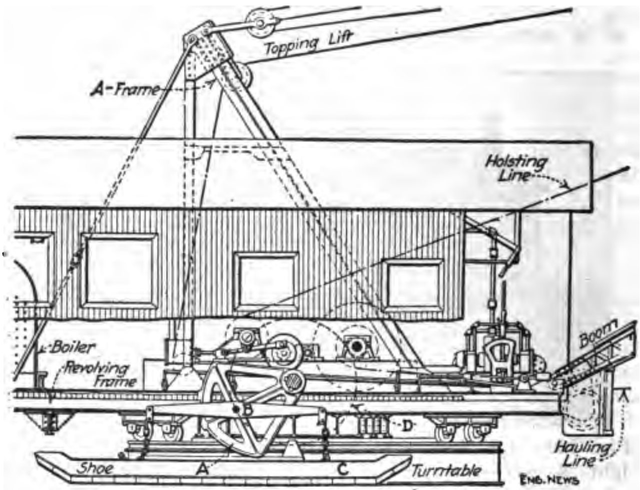

Fig. 13. Walking Mechanism of Monighan Walking Excavator.

The machine shown in Fig. 12 is at work on a drainage ditch 3½ mi. long, near Wheeling, Ill., the contract involving about 100,000 cu. yd. of excavation. The ditch is 10 ft. wide on the bottom, with side slopes of 1:1 and a depth of 5 to 10 ft. There is a 15-ft. berm and a spoil bank on each side for the greater part of the distance, but in some places these are on one side only. The machine has a 50-ft. boom and handles a 2½-yd. scraper bucket. Its turntable track is 17 ft. diameter. The two shoes or side platforms are 20 x 4 ft., each composed of two 12-in. I-beams with ⅝-in. cover-plates on top and 3-in. oak planks bolted to the bottom flanges.

The boiler is of the locomotive type, carrying 125 lb. pressure

and there is a 750-gal. water tank. The weight of the machine is about 65 tons. A larger size is made, having a 24-ft. turntable, 65-ft. boom and 3½-yd. bucket; this weighs about 85 tons. The machines may be operated by gasoline engines or electric motors if required.

These "walking" drag-line excavators are built by the Monighan Machine Co., of Chicago. The walking mechanism is the invention of O. J. Martinson.

Ditching with Special Plows. The simplest ditch can be dug with an ordinary plow. For this purpose a turning plow is used. A furrow is turned from 6 to 10 in. deep, and the plow in returning throws the earth in the opposite direction, giving a ditch on the bottom from 6 to 12 in. in width. The earth is thrown to each side of the furrow.

A better ditch can be excavated for either drainage or irrigation work by first plowing four furrows with an ordinary plow and then by using a shovel plow, which has a square bottom mold board, flat like a shovel with a 14 or 16-in. blade, the plowed earth is pushed to each side, leaving a ditch from one to two feet wide and from 8 to 12 in. deep.

A wing plow, which has a long mold board, can also be used to excavate a ditch. More efficient work can be done by first plowing the ground as is done for the shovel plow.

A lateral plow, which is the name given to a plow used in irrigation countries, is made by bolting together the beams of a right hand and a left hand plow. The shears are spread out, and rounded instead of being pointed. On top of the mold boards are riveted two other mold boards taken from other plows. Wide handle bars are bolted to the plow and well braced to the beams. Such a plow is drawn by from 4 to 8 horses, according to the character of the soil and the depth of the ditch to be made. One operation of this plow turns two furrows, one to each side of the ditch, throwing the dirt high on the ground. A ditch with a clean bottom about 2 ft. wide is left. A tool of this kind should have extensive use in many sections of the country. The excavated earth could be afterwards leveled off with a two-horse grader or leveler.

Ground can also be broken with a plow and then pushed to either side with an A-shaped drag, such as is used to clean paths through snow, made either of steel or timber. The bottom of the timber should be shod with iron.

Ditching with Cable Operated Plows. *Engineering News*, Feb. 3, 1916, gives the following:

For excavating the smaller sizes of farm ditches, too small for the use of a floating dredge or a land dredge, a ditching plow

was invented about 40 years ago in western Indiana. It has a double moldboard and cuts a ditch about 4 ft. wide on top and 2 ft. deep, with a bottom width of less than 1 ft. To draw this plow, 80 oxen were used, making the ditch at one cut. This type of ditching machine finally developed into a standard outfit, con-

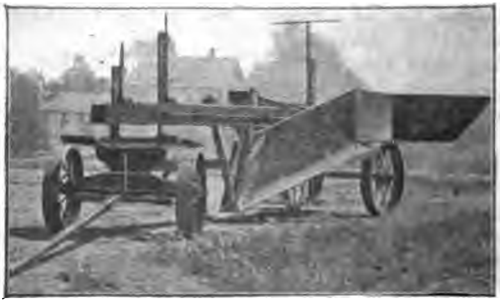

Fig. 14. Plow for Ditching by Horse Traction. The plow, shown in raised position, is fitted with a side wing to form a berm along top of ditch.

sisting of one plow and two capstans, using several thousand feet of steel cable with each rig.

Work of Horse Capstan Plows. With this outfit the plow will cut a ditch 8 ft. wide on top, 18 in. on the bottom and

Fig. 15. Capstan for Ditching by Horse Traction. The long horizontal pole is the sweep by which the horses turn the drum and the inclined timbers (one on each side) are anchors.

about 3 ft. deep. It is drawn by two ¾-in. steel cables, one from each capstan, both being operated at the same time. It makes a ditch with one cut, either dry or under water, and places on both sides of the ditch the earth excavated, pushing the earth

back so as to leave a clean berm of 3 ft. The two capstans used to draw the plow are self-anchoring and have 14-in. vertical drums, each drum holding 1,000 ft. of cable.

Four heavy horses are used on each capstan, working abreast and pulling at the end of a sweep that is attached direct to the drum. This sweep is usually about 24 ft. long, and the horses describe a circle nearly 50 ft. in diameter in order to wind in 3 or 4 ft. of cable. The work is so severe that relays of horses are used, and there are usually about 20 horses with each ditching rig.

These horse-driven ditching plows cut about 100 rods, or 1,650 ft. of ditch per day. In Wisconsin they frequently cut 50 miles

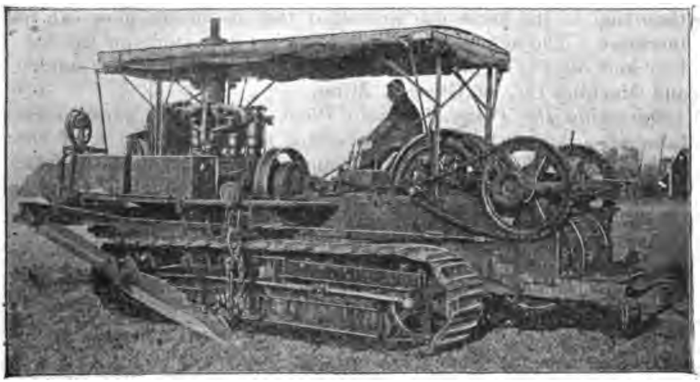

Fig. 16. Caterpillar Tractor with Drum for Hauling the Ditching Plow. When plowing, the tractor is stationary and is anchored by the inclined spuds while the 60-hp. engine drives the drum for winding in the plow cable.

of ditch in one season at a contract price of from $1.25 to $2 per rod of ditch, depending upon the character of the soil. Ditches made in stony or timbered lands are the more expensive.

Power Operated Capstan Plows. A gasoline tractor supported by two long caterpillar wheels 30 in. wide carries a cable drum (Fig. 16). Two anchor flukes, 2 x 10 ft. are placed near the front of the machine, one on each side. They are held at the proper angle by heavy chains attached to the frame of the tractor. These anchors hold the power capstan stationary when the plow is being pulled forward to cut the ditch.

The 1⅜-in. steel pulling cable is wound upon a large built-up cast-steel drum attached to the rear of the machine. This drum is 24 in. long, 16 in. in diameter, with flanges 36 in. in diameter. It is driven by two heavy link-belt chains from the main driving shaft of the tractor and is so back-geared that when the 60-hp. motor is running at its normal speed the drum winds in the pulling cable at a rate of 14 to 18 ft. per min., depending upon the amount of cable on the drum. The drum holds about 1,000 ft. of cable. When greater length is required, on account of inaccessible grounds, etc., removable sections of 500 or 600 ft. of cable are used to attain the desired length.

It has been found that the pulling power is so much greater than that of the horse machines that the size of the plow can be increased. The new plows will cut ditches 2 ft. wide on the bottom and 3½ ft. deep. They are made by the Glencoe Foundry and Machine Co., of Glencoe, Minn.

Operating the Power Ditching Plow. The power capstan retains its original feature as a tractor and is used to haul the plow which weighs 4 tons when mounted on its removable trucks. It also hauls a wagon loaded with cable and supplies, and a boarding cabin mounted on wheels. It takes this outfit over ordinary country roads at the rate of about 2 mi. per hr. The machine weighs about 15 tons; but owing to its large bearing surface, it can travel under its own power over swamp lands too soft to support a team. It is driven by a four-cylinder four-cycle gasoline engine of 60 hp., which also furnishes power to drive the winding drum.

In operation the plow is left at the starting point of the ditch, the cable being attached to the beam of the plow. Then the power capstan moves ahead to some point on the line of the ditch to be cut, paying out the cable as it advances. When this point is reached, the traction gear is released and the winding apparatus to the drum is thrown into gear. The anchors are released, allowing the points to drop to the ground. As the cable to the plow becomes taut, it draws the machine backward, causing the anchor flukes to enter the ground until the tractor with its capstan becomes firmly anchored.

When all the cable is wound on the drum, or a change in the direction of the ditch is to be made, the winding gear is thrown out of action and the traction gear is thrown in. As the tractor then advances, it pays out the cable and withdraws the anchors, which are hooked up clear of the ground by power, and the machine proceeds to a new point of setting, as determined by the foreman.

The power capstan is operated by one man and a helper; one man rides on the plow, and a team with driver is used in hauling supplies to the camp and to the machine. A cook in the portable cabin on wheels furnishes the food for the crew. A foreman directs the movements of the whole outfit.

Ditching with Cable Plow Operated from Barges. In ditching land that is too soft to permit the operation of a caterpillar traction ditcher, or other traveling plants, either hand work, or the use of some sort of ditch plow operated from barges is the only alternative. According to A. M. Shaw, in *Engineering*

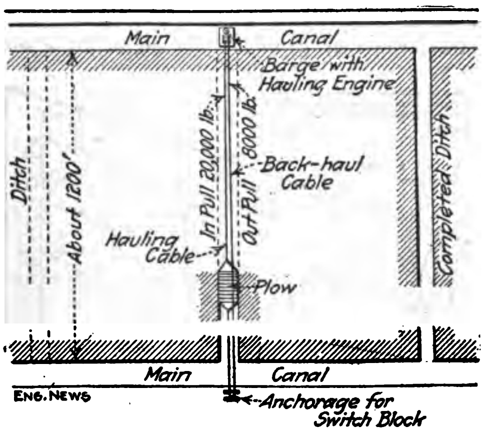

Fig. 17. Method of Excavating Ditches by a Cable Operated Plow.

News, Aug. 14, 1913, ditches in soft ground were excavated with an outfit consisting of the following: (1) two barges, 16 by 20 ft.; (2) a special compound-geared pulling engine, made by Clyde Iron Wks.; (3) two lengths of ¾-in. steel cables, each 1,350 ft. long; (4) one length of light message cable; (5) one ditching plow. The engine has 7 by 10-in. cylinders and a vertical boiler (4 by 9 ft.) carrying 100 lb. pressure. The total weight of boiler and engine is about 9 tons.

The power plow consisted of a heavy log forming the main stem or keel, with a long steel "coulter" hinged to the under side. This "coulter" was made from a steel bar about ¾ in. thick, 4 in. wide and 4 ft. long. The pulling cable was attached to the top, and another cable was also attached to the top of

the "coulter" and carried back by an adjustable hitch on the top of the center log. This latter cable was used for regulating the depth of cuts. From the front end of the log extended two heavy plank wings or mold board.

The method of working was to excavate two main canals about 1,200 ft. apart, and to open the land between them by a series of connecting ditches (Fig. 17). On one canal a ditching plow was floated while on the other canal was a barge carrying the pulling engine. A steel cable ran from the plow to the forward drum of the engine, capable of exerting a 20,000-lb. pull. This cable pulled the ditching plow through the intervening 1,200 ft. of ground at a speed of about 3,000 ft. per hr. Another cable ran from the rear drum of the engine to a snatch block

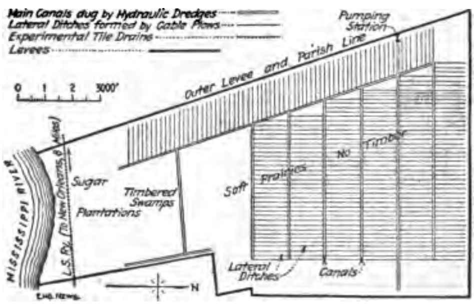

Fig. 18. Plan of a Canal and Ditch System for Drainage of a Tract of Swamp Land in Louisiana.

on the farther bank of the lower canal, and thence to the rear of the plow. This latter drum (single-gear) exerted a pull of 8,000 lb. to haul the plow back through the newly dug ditch to the canal, whence it was floated down to the next proposed ditch and the operation was repeated.

It was not found practicable to cut a ditch more than about 30 in. deep with this device, and it lacked the adjustable features of a more elaborate ditching machine. It had the following advantages: (1) low first cost; (2) economy of operations; (3) simplicity; (4) easily transferred, as the plow is pulled into the canal and floated from one ditch to the next.

One month, 156 quarter-mile ditches (or 39 miles) were cut with the plow, each ditch being gone over twice. The ditches averaged about 30 in. deep, 2 ft. wide at the bottom and 3 ft. wide on top. The cost of operating the plow, including repairs,

fuel, etc., amounted to about 5 ct. per cu. yd. A crew of 10 to 12 men was required.

Ditching by Explosives. Explosives if properly used will excavate ditches and spread the material removed. The flow of water is depended on to clean out the bottom. Holes in stiff clay or hard pan should be 26 in. apart along the ditch, and in loose mucky soil 30 in. apart. They should be punched or bored to within 6 in. of the desired depth. In strongly sodded soil, cut with a spade along the side lines. All holes in the ditch should be blasted simultaneously with a battery if possible, or placed closer together, 18 to 24 in. apart along the ditch, and exploded by concussion from the middle hole, that one being detonated by a fuse and cap. Tables I and II give the required charges. Dynamite of 20% grade is ordinarily used, but in stiff tenacious soil 40% is better. When the material is soft at top and hard at bottom, use 40% dynamite in the bottom of the charge and 20% in the top.

TABLE I — OF CHARGES FOR DITCH BLASTING (USING BATTERY)

Top width of ditch in ft.	Number of cartridges required for various depths 2½ to 3 ft.	4 ft.	5 to 6 ft.	Number of rows of holes required	Distance between rows, in.
3	½			1	
6	1	2	3	1	
8	1	2	3	2	20
10	1	2	3	2	28
12	1	2	3	2	36
14	1	2	3	2	42
16	1	2	3	3	42
Required length of No. 6 Victor Electric Fuses..........	4 ft.	6 ft.	6 to 8 ft.		

Distance apart in rows depends on nature of soil.

TABLE II — OF CHARGES FOR BLASTING DITCH (WITHOUT BATTERY)

Top width of ditch	Approximate number of cartridges per hole required for various depths 2½ to 3 ft.	4 ft.	5 ft.	6 ft.	Number of rows required	Distance between rows, in.
6	1	2	2½	3	1	
8	1	2	2½	3	2	30
10	1	2	2½	3	2	36
12	1	2	2½	3	2	42
14	1	2	2½	3	2	48
16	1	2	2½	3	3	36
18	1	2	2½	3	3	42
20	1	2	2½	3	3	48

Distance apart in rows depends on nature of soil.

For methods of blasting see Chapter V. Also see my "Handbook of Rock Excavation."

Three Examples of Cost of Ditching by Dynamite. The following work done at Chadbourne, N. C., for the Brett Engineering Co., as reported in *Engineering and Contracting*, May 8, 1912.

Where the ground was comparatively free from stumps and roots holes were put down 18 in. apart, 3½ ft. deep, and 100 holes in all. Each hole was pointed 45° and loaded with one stick of Hercules 60% N. G. dynamite 1¼ x 8 in., the center hole being primed with an extra stick and a double strength exploder. See Fig. 19. The result was a good ditch 7 ft. wide on top, 3 ft. on the bottom and 3 ft. deep and 150 ft. long. Costs of finishing and trimming according to specifications per running foot were:

Explosives	$11.35
Putting down holes	.50
Finishing and trimming	4.50
Total cost of 150-ft. ditch	$16.35
Total cost per running ft.	0.109

The next ditch was shot at Sollo Swamp, where the ground was heavily matted with roots and stumps. The specifications here called for a ditch 14 ft. wide, 2½ ft. deep. A double row of holes were used, 100 in each row, 18 in. apart laterally, 4½ ft. apart longitudinally, and 4 ft. deep. Both rows pointed 45° in the same direction. The middle holes were primed with an extra stick and a double strength exploder. Along the path of this ditch there were 35 stumps from 6 in to 3 ft. in diameter. The result was a clean ditch 12 to 14 ft. wide, 4 ft. deep and 150 ft. long.

Explosives per running ft.	$0.100
Holes per running ft.	.007
Labor per running ft.	.030
Total cost per running ft.	$0.137

The next ditch was shot at Dunn Swamp, 150 ft. long in the muddiest and stickiest kind of ground. A double row of holes was used, 18 in. apart, 4½ ft. laterally, 4 ft. deep, both rows pointed 45° in the same direction. Each hole was loaded with one stick of 60% dynamite and the middle hole of each row was primed with a double strength exploder. All the holes were well tamped. The result was a very clean ditch 14 ft. wide, 3½ to 4 ft. deep and 150 ft. long. The total cost of this ditch was the same as the ditch shot at Sollo Swamp.

A drainage ditch 2,600 ft. long, containing 1,732 cu. yd., was blasted out with 1,400 lb. of 60% nitroglycerin dynamite. The method used was to prime the center holes in a line 300 to 500 ft. long with fuse and caps. According to B. L. Jenks in the

DuPont Magazine for June, 1914, the land was very wet and it would have been impossible to use teams or a ditching machine. To have dug it by hand would probably have cost at least 33 ct. per cu. yd. The total cost by the dynamite method was $383 or 22.1 ct. per cu. yd., itemized as follows: Dynamite delivered

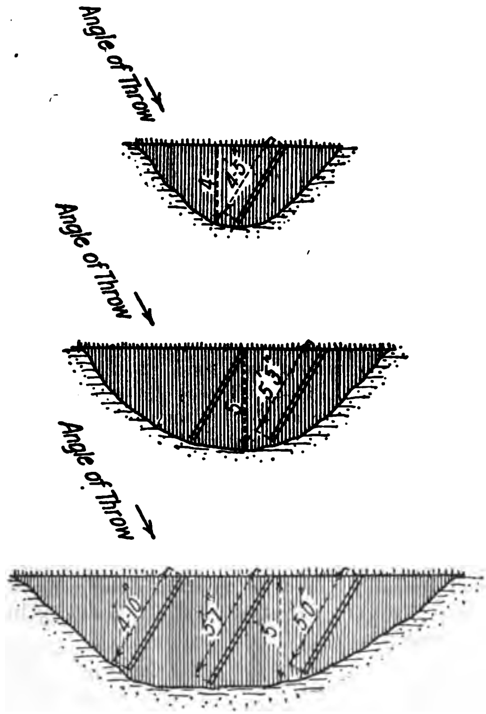

Fig. 19. Arrangement of Holes for Excavating Ditches with Dynamite.

on land, $278; labor putting down the holes and shooting, $104; fuse and caps, $1.

Arthur E. Morgan, in *Engineering and Contracting*, Feb. 1, 1911, gives the following about ditching in southeastern Missouri:

One of the ditches examined, which had been constructed about a year, was 6 ft. wide on the bottom, 12 ft. wide on top, 3½ ft.

deep, and in good order. In digging it two ½-lb. sticks of 50% dynamite were placed 3 ft. apart in the ground and between 3 and 4 ft. deep. Two men construct a quarter of a mile of ditch in a day.

At a cost of 15 ct. per pound for dynamite, and $20 per mile for placing the charges, the ditch had cost about 5 ct. per cu. yd. The ditch had been constructed through the woods without cutting down any of the trees, and in some instances the fallen trunks were lying across the channel.

Cost of Ditching with Dynamite in Georgia. *Engineering and Contracting*, July 9, 1919, gives the following:

In connection with the anti-malarial preparations of the U. S. Public Health Service in the extra cantonment zone at Camp Wheeler, Ga., dynamite was used in the ditching work. The best results were obtained in mucky areas where the mud was so deep and soft that hand excavation became slow and difficult. In these cases, the use of dynamite proved satisfactory. In a report on the work by the U. S. Public Health Service the following comparative costs of ditching by hand labor and with dynamite are given. The figures are for two adjacent ditches in a large swamp in the extra cantonment zone. Ditch No. 60 was excavated with dynamite. This ditch was 2,802 ft. long, 12 ft. wide at the top and 4 ft. wide at the bottom, and averaged 5 ft. deep. The number of cubic yards of material removed was 4,151. Ditch No. 62 was excavated by laborers with picks and shovels. This ditch was 3,591 ft. long, 4 ft. wide and 3 ft. deep. The yardage was 1,596. The cost of excavation in the case of ditch 60 includes clearing out the ditch after it was dynamited. In the case of ditch 62 the cost of excavation includes the cost of a small quantity of dynamite used to facilitate the removal of large stumps. The costs of excavating each ditch, not including clearing, were as follows:

	Ditch 60.	Ditch 62.
Cubic yards	4,151	1,596
Labor cost	$308.90	$671.75
Cost of material	$1,265.10	$38.75
Cost of excavation	$1,574.00	$710.50
Cost per cu. yd.	$0.39	$0.45
Man days at $3	103	224
Man days per cu. yd.	0.024	0.140
Cubic yards per man day	41.66	7.14

The report states that it is probable that the cost of excavating ditch 60 by hand would have greatly exceeded 45 ct. a cu. yd., owing to the very difficult nature of the soil — a mass of yielding mud, largely under water, in which it was almost impossible to stand up.

Blasting a Ditch in Quicksand and Clay. *Engineering and Contracting*, Nov. 21, 1917, gives the following: At one of the plants of the American Brick Co. a channel 530 ft. long, extending through a tangle of underbrush, was successfully blasted. The soil is quicksand and clay. In blasting through the clay a hole was bored and cartridges pushed down with a stick, no tamping being necessary as the water filled the hole.

The strip of quicksand measured about 35 ft. across. Tin tubes about ½ in. longer than a stick of dynamite were made. Cartridges were encased in the tin tubes and then pushed down into the quicksand.

The cartridges were spaced about 2 ft. apart, both in the quicksand and in the clay. In one hole the charge consisted of 1½ cartridges. The next hole contained 1 cartridge. And so on alternately down the line. The cartridges were put down to a depth of about 2½ ft. The resulting shot gave a ditch about 3 ft. deep and 6 ft. wide.

Ditch Excavation by Scrapers. When scrapers are used, with the exception of power scrapers, the ground must first be loosened by a plow. Two useful scrapers for small ditches are the Chicago Tongue Scraper and the Haslup Side Scraper. These are described and illustrated in Chapter IX.

The rotary scraper can also be used for ditch excavation. This is a California invention. The scraper consists of a square pan that revolves about two fixed points in a frame made up of the bail and the handles, instead of being attached rigidly to the handles as is a drag scraper. The scraper is loaded in the usual way, and is dumped by the driver releasing a catch at the handle, thus allowing the movement of the scraper to dump itself.

The other styles of scrapers can all be used either in excavating small or large ditches. However, the ground must be dry enough to allow horses to walk over it without becoming mired. Even if horses sink but a few inches into the ground as they walk, their work is greatly retarded. Drag scrapers operate poorly in very wet places. The suction of water on the bottom of the pans makes the work hard for the horses, but in dry material good work can be done, even when pulling up steep slopes. However, where the ditch is large enough, buck or Fresno scrapers can be used instead of drag scrapers; and with leads less than 60 ft. more economic work will be done. Ditches 6 to 8 ft. deep can readily be dug with buck scrapers. The mass of the yardage can be moved with them and then drag scrapers can be used to finish and dress up the work.

For deep ditches and where the haul on the excavated

material is long, wheel scrapers will be found superior to either drags or buck scrapers. But the ditch must be wide enough for two teams to pass one another, or else the loaded scraper cannot get by the snatch team without delaying the work.

Another kind of scraper that can be used to advantage in ditch construction is the Maney four-wheel scraper. This scraper has been described in Chapter IX.

Power scrapers are also well adapted to ditch construction. Some form of a derrick car or movable derrick is used to operate the scrapers. Descriptions of power scrapers are given in Chapter XIV.

Cost of Excavating Ditches with Drag Scrapers. The output of scrapers at the experimental farm of the University of Minnesota is given in *Engineering and Contracting*, Oct. 21, 1908. The ditches were about 3 ft. deep and 4.65 ft. wide. The scrapers were for the most part used for finishing up ditches excavated by elevating graders. On one ditch a drag scraper excavated at the rate of 43.5 cu. yd. per day, and on another at the rate of 41 cu. yd. per day. Each scraper required the services of 1 team and 1.5 men. The contractor acted as his own foreman handling the teams in gangs of 4 to 6 scrapers. With wages for laborers and drivers at $2.00 per day, the cost of horses at $1.50 each, and allowing $3.00 per day for the services of a foreman, the cost per cu. yd. was 16 ct. On other ditches an experienced ditch man and team excavated at the rate of 65 cu. yd. per day, and a contractor with 2 teams and 3 men in a gang averaged 100 cu. yd. per gang per day, or 50 cu. yd. per scraper.

See Chapter IX for other cost data.

Cost of Main Canal for Payette-Boise (Idaho) Irrigation Project. *Engineering and Contracting*, Sept. 16, 1908, gives the following:

Work under the contract was begun in Feb., 1906, and was completed in March, 1908. The total amount invested by the contractor and sub-contractors in plant was estimated to be $39,836, $28,230 of which was invested in teams and harness. In estimating interest charges the value of horses and harness was not included as they were considered in the cost records at current rate of wages for teams.

During the first portion of the contract laborers worked 10 hr. per day, but during the latter portion an 8-hr. day.

The following current wages were paid for an 8-hr. day: Superintendent, $125 per month; time-keeper, $100 per month; foreman, $3 to $4 per day; powder man, $3; drivers, $2.50; common labor, $2.25; stable boss, $67 per month.

No materials were furnished by the contractor, but considerable supplies were needed in conjunction with the excavation of rock. Coal delivered on the work cost $9 per ton, black powder $2 per keg, giant powder $0.15 per lb., and lumber $22 per M. ft. B.M.

The greater part of Class I excavation consisted of a stiff loam containing a considerable amount of clay with loose rocks of various sizes scattered through the mass. About one-half of this material was handled with Fresno scrapers, the remainder being handled in wheel and drag scrapers. Nearly all of the excavation was taken from the canal prism, there being very little taken from borrow pits.

Class 2 excavation consisted of indurated material that could be plowed by 10 horses. This material was usually found beneath Class 1 material, and after plowing consisted mainly of a mass of lumps of earth of various sizes. The lumps were broken by the passage of horses and scrapers over them, and were loaded and hauled by means of Fresno and wheel scrapers.

Class 3 excavation consisted of indurated material that required blasting before it could be removed, but that could be removed by the use of wheel scrapers. This material occurred locally and was found usually near the grade plane of the canal.

Class 4 excavation consisted of boulders less than one-half cubic yard in volume that would prevent plowing and the use of scrapers, and was scattered quite generally throughout Class 1 material. These boulders were usually removed by means of stone boats working in conjunction with wheel or Fresno scrapers.

Class 5 excavation consisted of boulders exceeding one-half cubic yard in volume and solid rock, requiring blasting for removal. All drilling was performed by hand and a greater part of the blasting was done with black powder, though a small amount of giant powder was used. About two-thirds of this class of material was encountered in three of the heavier cuts, the remainder being scattered along the entire length of the canal. This material was moved by means of stone boats, but horse power derricks were used, together with the stone boats, in the deeper cuts with less satisfactory results.

Table I gives the cost of the work.

The following was the yardage of each class:

Class 1	467,785
Class 2	69,009
Class 3	20,303
Class 4	10,933
Class 5	85,828
Total cu. yd.	653,858

There were 207,074 cu. yd. of "overhaul" that cost 2.3 ct. per. cu. yd.

TABLE I. COST PER CU. YD. ON MAIN CANAL, PAYETTE-BOISE IRRIGATION PROJECT

	Class of Excavation				
	(1)	(2)	(3)	(4)	(5)
Interest on investment	$.002	$.005	$.008	$.009	$.017
Preparatory expense	.001	.002	.004	.004	.008
Plant depreciation	.003	.006	.008	.009	.020
Repairs	.006	.011	.014	.017	.042
General supplies	.001	.002	.004	.003	.007
Superintendence	.014	.025	.031	.033	.092
Grubbing right of way	.001	.001	.002	.001	.002
Plowing	.019	.056	.058	.085	...
Drilling by hand	...	...	.057	.021	.209
Explosives and drill steel	...	...	.098	.029	.225
Loading, hauling and spreading	.089	.164	.255	.294	.507
Finishing	.006	.016	.021	.032	....
Water, original cost, and hauling.	.001	.003	.001	.001	.004
Contractor's total cost	.143	.291	.561	.538	1.133
U. S. engineering	.007	.016	.022	.035	.046
Total cost	$.150	$.307	$.583	$.573	$1.175

Cost of Canal Excavation for Uncompahgre Irrigation Project, Colorado. *Engineering and Contracting*, Nov. 18, 1908, gives the following:

The work covered 4,400 lin. ft. of the South Canal, which was begun in June, 1907, and completed in May, 1908, at a total cost of $22,932. The canal has a bottom width of 40 ft., side slopes of 2 to 1, water depth of 8.3 ft., and a discharge of 1,175 second-feet.

Class 1 excavation contained all material that could be plowed by an average six-horse team, each animal weighing not less than 1,400 lb., attached to a suitable breaking plow, and also all isolated masses of rock not exceeding ½ cu. yd. in volume. Class 2 excavation consisted of material originally of the nature of Class 1, but so saturated with water as to render the use of teams in the ordinary manner impossible. Class 3 excavation consisted of indurated material of all kinds that could not be plowed as Class 1, or that required loosening with powder before being removed in scrapers, and also all loose material in which large rocks occurred to such an extent as to prevent the use of plows and scrapers, excluding masses exceeding 1 cu. yd. in volume. Class 4 excavation consisted of rock in masses greater than 1 cu. yd. in volume and requiring drilling and blasting before removal. The limit of free haul was 300 ft. About 73% of the material was removed with drag, Fresno and wheel scrapers, about 27% with a slip and chain, and the remainder with shovels and wheelbarrows.

The weather conditions were good for the performance of work throughout the continuance of the contract, and the management was good with the exception of insufficiency in the number of foremen employed. Labor was scarce and high. On the excavation laborers were paid at the rate of from $2.25 to $2.50 per day; foremen at the rate of $3 per day and the superintendent at the rate of $122.50 per month.

The yardage was as follows:

Class 1	24,194
Class 2	15,054
Class 3	17,058
Class 4	100
Total cu. yd.	56,406

There were 6,600 cu. yd. of "overhaul" that cost 1.7 ct. per cu. yd.

The unit costs of the different classes of work are given in Table I.

TABLE I. COSTS PER CU. YD. OF EXCAVATION OF IRRIGATION CANAL, UNCOMPAHGRE PROJECT, COLORADO

	Class 1	Class 2	Class 3	Class 4
Interest	$0.002	$0.005	$0.003	$0.006
Plant depreciation	0.002	0.006	0.004	0.008
Executive	0.028	0.070	0.048	0.062
Labor	0.197	0.503	0.339	0.439
Supplies	....	0.002	0.001	0.260
Contractor's total cost	$0.229	$0.586	$0.395	$0.775
U. S. materials	....	....	....	....
U. S. engineering	$0.013	$0.009	$0.012	$0.001
Total cost	$0.242	$0.595	$0.407	$0.776

Cost of Huntley Irrigation Canal. *Engineering and Contracting*, Jan. 20, 1909, gives the following:

Division 1 of the Main Canal of the Huntley Project contains a section of about 390 ft. in length, having a depth of 17 ft., a base of 14.5 ft. and side slopes of ½ on 1. In addition to the material covered in this prism, there were about 2,000 cu. yd. of material excavated above the general level on one side of the canal extending to the top of a cliff along the base of which the canal takes its course. The work of excavation of this section of the canal was done by contract, and below is given a summary of the cost of the work to the contractor.

The excavation was divided into the three following classes: Class 1, earth or material that could be plowed and handled with scrapers; Class 2, loose rock varying in volume from 2 to 20 cu. ft.; Class 3, solid rock or material not included in either

of the foregoing classes. Most of the material consisted of a bluish gray sandstone of medium hardness and was paid for under Class 3.

The material excavated from the main prism of the canal was loosened by blasting with 40% gelatine dynamite. All drilling for blasting was done by hand. About two-thirds of the material was removed in small cars of ½ cu. yd. capacity. The finer portions of the remainder were loaded by hand into one-horse dump carts and hauled a distance of about 200 ft.; and the larger pieces were rolled onto sheet steel sleds, which were unloaded by driving the sleds over the side of a near-by dump, causing the rock to roll off the sled. The material taken from the cliff above the canal prism was handled in the same manner as the coarser portions from the canal prism.

The principal superintendent was paid at the rate of $6.67 per 8-hr. day; the assistant superintendent, $5.75; the foreman, $3.25; laborers, from $2 to $2.40; single horse and cart, $1; team and car, $2; team and driver, $4; blacksmith, $2.80.

In Table I the cost of the principal and assistant superintendent and the foreman has been charged under Executive, the cost of all other work under Labor, and the cost of coal, oil and blasting material under Supplies.

TABLE I. COST PER CU. YD.

	Class 1 391 cu. yd.	Class 2 1,507 cu. yd.	Class 3 6,427 cu. yd.
Executive	$0.009	$0.139	$0.127
Labor	0.094	0.646	0.905
Supplies	.....	.....	0.103
Total	$0.103	$0.785	$1.135

Cost of Klamath Irrigation Canal. *Engineering and Contracting*, May 19, 1909, gives the following:

About 12.3 miles of South Branch Canal on Klamath Project were constructed under two contracts during the season of 1908 and part of 1909. The upper end of the canal is about 8 miles from Klamath Falls, and the whole of the work was divided into eight schedules averaging about 1½ miles in length. Schedules 1, 2 and 3 were constructed under contract, the greater part of the work being done from May to December, 1908. The excavation of about 8,000 cu. yd. on schedule 1 was delayed until the spring of 1909 and was finished in March. On schedules 1 and 3 the bottom width is from 15 to 18 ft. and the slopes are 1½ to 1. On schedule 2 the canal is built entirely in embankment with a bottom width of 3.8 ft. and on side slope of 1½ to 1. On this schedule the material for the outer triangles

TABLE I — COST OF EXCAVATING SOUTH BRANCH CANAL, KLAMATH IRRIGATION PROJECT

Schedule No.	1	2	3	4	5	6	7	8
Length, miles	1.27	1.36	3.0	1.3	1.33	1.33	1.33	1.56
Quantity, cu. yd.	54,734	163,987	71,895	21,116	23,209	22,613	23,035	27,933
Total cost	$3,077	$30,230	$10,212	$4.210	$3,710	$2,660	$3,670	$4,750
Per cent. of indurated material	23	0	5	5	1	0	1⅔	0
Winter work	2 mos.	none	none	2 mos.	none	none	none	1 mo.
Cubic yards (per man day)	23	33	36	22	32	44	31	27
Cubic yards (per horse day)	16	17	23	15	18	28	20	17
Interest	$0.005	$0.003	$0.003	.....	.....	.....	.....	.....
Preparatory expense	.009	.006	.008	$0.002	$0.002	$0.002	$0.002	$0.002
Depreciation	.007	.006	.004	.003	.003	.003	.003	.003
Executive	.016	.008	.007	.008	.008	.008	.008	.008
Superintendence	.012	.006	.003	.014	.007	.007	.009	.013
Labor:								
Plowing, men	.014	.006	.008	.013	.009	.006	.008	.009
Plowing, horses	.013	.008	.008	.014	.009	.004	.010	.008
Scraping, men	.045	.033	.027	.033	.028	.019	.023	.027
Scraping, horses	.048	.050	.033	.052	.048	.032	.041	.050
Loading and dumping	.018	.010	.008	.021	.012	.010	.014	.014
Sprinkling and rolling	...	.003	...	...	...	...	...	...
Finishing and sloping	.007	.005	.008	.014	.011	.006	.013	.016
Miscellaneous	.009	.007	.003	.008	.007	.006	.012	.004
Supplies	.024	.021	.009	.006	.005	.003	.005	.005
Engineering and inspection	.013	.013	.013	.011	.011	.011	.011	.011
Total cost per cu. yd.	$0.240	$0.185	$0.142	$0.199	$0.160	$0.117	$0.159	$0.170

of the canal banks, amounting to about 40% of the total, was deposited in 12-in. layers in the ordinary manner of building embankments, but the other 60% of the material was deposited in 6-in. layers, sprinkled, and rolled. Schedules 4, 5, 6, 7 and 8 were constructed under formal contract and informal specifications, the greater part of the work being done from August to December, 1908. A small amount of work on schedules 4 and 8 was done in the winter of 1908–9, and finished in March, 1909. For all of schedules 4, 5, 6, 7 and 8 the bottom width of canal is 11.5 ft. and the side slopes 1½ to 1.

On all schedules most of the material excavated was earth that could be plowed by six-horse teams, and in general no bad conditions were encountered. A small amount of indurated material that required blasting before scrapers could be used was encountered, but no separate estimate of the cost of excavating this material was kept. The per cent of this material in terms of the whole amount of excavation on the several schedules is, however, tabulated with the unit costs.

On the first contract, covering schedules 1, 2 and 3, an estimate of interest on investment is made at 6% per annum on the estimated value of animals and equipment. For the second contract, covering the other schedules, no estimate of interest on investment has been made. For both contracts an estimate of depreciation of equipment has been made at 2% per month on the total value thereof. The weather and labor conditions were generally good under both contracts. The wages for common labor were $2 per day, and the cost of animals, including depreciation, was estimated at $1 per day each.

Table I gives the unit costs of the work, including cost to the contractors and the engineering expenses of the United States, together with other useful information relating to the work.

Using an Engine Instead of a Snatch Team to Load Scrapers. In the construction of a canal in connection with an irrigation scheme, part of the material was removed by means of wheel scrapers. The canal was to be 40 ft. wide at the bottom, with 1 to 1 side slopes, varying in depth up to 42 ft. The canal was dug mostly in clay, but there was some rock. The spoil was placed alongside of the cutting, leaving a berm 30 ft. wide. Part of the material was removed by scrapers of about 16 cu. ft. capacity drawn by two horses. An ordinary winding engine was used instead of an extra team of horses for loading the scrapers. The engine was placed on the bank, close to the edge of the excavation, so that the ⅝-in. wire hauling rope might pass either way about 300 to 400 ft. along the canal. The hauling rope was attached and detached at the pole of the scraper by a la-

borer; a pony driven by another attendant was used to drag the rope from place to place for this laborer. In order to prevent the scraper cutting too deeply and to prevent undue pressure on the necks of the horses a gage wheel was used under the rear end of the pole.

Cost of Canal, Milk River Project. A. E. Bechtel, in *Engineering and Contracting*, Sept. 20, 1916, gives the following:

The earth work of the second unit of the Dodson North Canal, Milk River Irrigation Project, near the town of Malta, Mont., was begun on Sept. 1, 1913, and completed on Sept. 1, 1914, by contract. There were 230,000 cu. yd. of excavation in canals and 70,000 cu. yd. in waste water ditches. The canals were from 5 to 10 ft. bottoms with a slope of 2 to 1, and contained from 100 cu. yd. to 1,300 cu. yd. to the station of 100 ft., averaging about 400. Approximately 20,000 cu. yd. was wet and 30,000 cu. yd. was hillside work.

The waste water ditches had from 3-ft. to 20-ft. bottoms (mostly 3 ft.) with a slope of 1½ to 1, and averaged about 100 cu. yd. per station; 10,000 cu. yd. was wet excavation. About 35,000 cu. yd. were cast into the canal banks with an Austin reversible elevating grader pulled by a 30–60 hp. Pioneer gas tractor, and 25,000 cu. yd. of the excavation of the waste water ditches were cast out with an Austin senior elevating grader. These machines were operated two and three shifts during the fall of 1913 and one shift during 1914.

The remainder of the work, 240,000 cu. yd., was done with 5-ft. fresnoes, excepting the finishing of the waste water ditches, which was done with drag scrapers, and about 5,000 cu. yd. of over-haul done with wheelers. About 60,000 cu. yd. of the work was sub-contracted but the costs here are the costs to the sub-contractors.

The material excavated in the canals and laterals, other than that designated as wet, was average clay soil with more or less gumbo. The waste water ditches were mostly gumbo and baked so hard that in excavating it with a grader, it was hard to keep the plow in the ground.

The cost, to the contractor, of 134,517 cu. yd. excavated in 1913 was 21.3 ct. per cu. yd., a typical section being No. 1 which contained 13,192 cu. yd. excavated by fresnoes at a cost per cu. yd. of:

	Ct.
Labor	8.2
Teams	6.3
Superintendence	2.4
Equipment	0.9
General expense	2.7
Total per cu. yd.	20.5

The cost of excavating 116,124 cu. yd. in 1914 was as follows:

Team Work —	
Superintendence	$0.0100
Foreman	0.0114
Plow	0.0160
Fresno	0.0771
Blacksmith	0.0012
Fence and grubbing	0.0005
Finishing	0.0028
Equipment, hardware and tools	0.0161
General expense	0.0038
Labor, erecting, moving and maintaining camp	0.0014
Cook	0.0044
Labor, hauling camp and table supplies	0.0020
Labor, maintaining stable	0.0036
Total, teams, 93,949 cu. yd.	$0.1503
Machine Work —	
Superintendence	$0.0024
Labor	0.0302
Gas and oil	0.0297
Repairs	0.0188
Equipment, hardware and tools	0.0683
Total machine, 22,175 cu. yd.	$0.1494
Total — Machine and teams, 116,124 cu. yd.	0.1501

The machine consisted of a Reversible Austin Elevating Grader and Pioneer Tractor.

Work on 48 structures (spillways, culverts, etc.) involving 17,644 cu. yd. of excavation and 8,115 cu. yd. of backfill, was done at an average cost of 61 ct. per cu. yd. of excavation, distributed as follows:

	Ct.
Foreman	2.0
Excavation	35.0
Backfill	7.0
Total field cost	44.0
General supervision	5.0
Equipment	5.0
General expense	7.0
Total	61.0

The material was clay.

In small jobs, where the clay was hard, the excavation usually cost about as follows, for a spillway excavation of 54 cu. yd. with no backfill:

Foreman	$0.17
Excavation	1.24
General supervision	0.13
Equipment	0.19
General expense	0.19
Total per cu. yd.	$1.92

In excavating for culverts in average clay, all the excavation being subsequently backfilled, the following was a typical cost.

Foreman	$0.03
Excavation	0.43
Backfill	0.12
General supervision	0.05
Equipment	0.07
General expense	0.08
Total per cu. yd.	$0.78

Use of Elevating Graders for Ditching. Elevating graders can be used for ditch construction, but in very wet ground they are barred as the horse or engine used to propel them would be mired.

For ditch work, especially where there is tough grass and small roots, a disc plow on a grader will do more efficient work than the ordinary turning plow. The disc plow also throws the material onto the elevating belt better. For such work the elevator should be extended to 30 ft. if the ditch is a wide one. It is in this class of work, where the material is thrown onto the banks, that an elevating grader reaches its greatest capacity.

One objection to an elevating grader in ditch construction is that the machine will not finish off the slopes or the bottom of the trench, as the plow runs irregularly. But the work can be done very cheaply, and the ditch can be finished off at small cost with road machines and scrapers.

For narrow ditches the machine is not very well adapted, a width of 8 ft. at the bottom being necessary, but in wide ditches it will do excellent work, and the cost of dressing up the ditch is proportionately smaller.

Fig. 20 (1–4) indicates the types of ditches that may be excavated with an elevating grader, and the methods of attacking the work. Fig. 20-1 shows a ditch 2 ft. deep and 4 ft. wide on the bottom with 1½ to 1 slopes. In cutting a ditch of this size a 15-ft. elevator is used. The earth is thrown from the left side of the cut to the right bank, and in returning it is thrown in the opposite direction. This method is known as "cross-firing." This is about the minimum size of ditch which can be practically excavated in this manner.

Fig. 20-2 shows a ditch which may be excavated by the use of two sizes of elevators. The first 2 ft. in depth is excavated with a 15-ft. elevator starting the cut along the outside of the ditch and working toward the center. The last 2 ft. is then excavated by an 18-ft. elevator, leaving a berm of about 2 ft. on each side.

Fig. 20-3 represents a ditch which is deeper than can be handled

ordinarily with an elevating grader. By using the following method, however, such a ditch can be successfully handled. Using a 21-ft. elevator the top 2 ft. are first excavated, and to a width 6 ft. beyond the required ditch line. This extra section taken out will be refilled from the bottom cut. The second

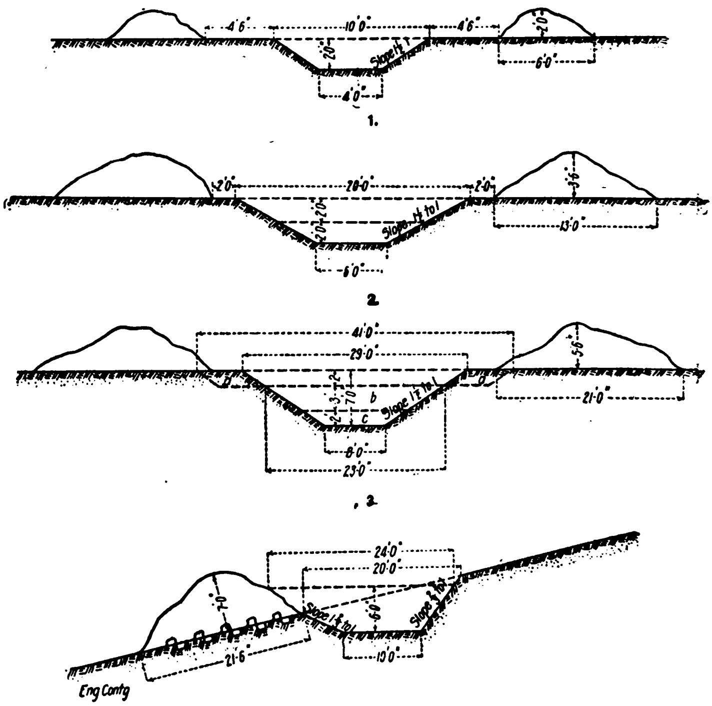

Fig. 20. Sizes of Ditch That Can Be Dug with Elevating Graders.

operation is to excavate the next 3 ft. in depth. This section is narrowed down to 23 ft. on top, this being the width of the required section of ditch as shown by this drawing. The first two operations will, in this case, take out 5 ft. in depth, using the method of working from the outer edges of the ditch toward the center. The third operation consists of cross-firing and depositing

the earth from the bottom of the cut into the sections lettered *a* in the figure.

Fig. 20-4 shows a side hill cut. This ditch cannot be so economically excavated as the others since the spoil bank is limited to one side of the cut and the machine operates in one direction only, making the return trip empty.

The downhill slope is usually plowed as indicated in the figure to prevent sliding of the embankment and to prevent the larger chunks of earth from rolling down hill. For a ditch of the dimensions indicated an 18-ft. elevator should be used.

The outputs of elevating graders excavating ditches for the drainage system of the Minnesota University experimental farm are given in *Engineering and Contracting*, Oct. 21, 1908. The ditches were excavated an average width of about 3 ft. at the bottom and a depth of 4.65 ft. On one ditch a grader removed 2,040 cu. yd. at the rate of 450 cu. yd. per day of 10 hr., and on another ditch it removed 4,000 cu. yd. at the rate of 1,000 cu. yd. per day. Sixteen horses and 4 men were required for the operation of a machine. If the rate of pay of men was $2 per day and of horses $1.50 per day each, the cost was 3.2 to 7.1 ct. per cu. yd. In finishing up these ditches drag scrapers were used.

See Chapter IX for other data on elevating grader work.

Ditch Excavation with a Grab-Bucket Excavator. *Engineering and Contracting*, Oct. 13, 1909, describes work done in the Modesto and Turlock districts along the San Joaquin river in California. An irrigation canal about 20 ft. wide on the surface, and 6 ft. deep with steep sides was dug. It was anticipated that the sides would cave, leaving a canal about 3½ ft. deep. Most of the soil encountered was sandy, hardpan lying under the sand at varying depths.

The dredge cost $5,000. It is of the type which moves in the axial line of the canal to be dug and recedes from the breast of the canal as it is excavated. It differs from the side line dredge in that its boom motion is produced by a turntable. The dredge machinery is mounted on a skid platform 18 by 30 ft., which rests on several movable wooden rollers run on planks placed on the ground. As the canal is excavated the dredge is moved 3 to 5 ft. at a time by means of a steel cable anchored to a "dead man" several hundred feet ahead of the dredge, and wound on a drum, which is power-driven by a worm gear from the engine. The tower or A-frame which supports the 40-ft. boom is 20 ft. high. This boom supports the cable sheaves for the bucket and inclines about 45°, but has no vertical motion, although it may be swung about 180° horizontally by a cable-propelled turntable located at the front of the dredge under the

tower. The bucket is a 1-cu. yd. capacity clam-shell type, weighing about 2,800 lb. The machine is controlled by means of three levers and two foot brakes, mounted on a platform on the A-frame. Power is furnished by a 25-hp. single-cylinder gasoline engine, which drives a series of combination gear and friction brake drums controlling the motion of the excavating bucket.

The following was the operating cost per month:

Crew:	
Foreman	$ 95.00
Assistant foreman	85.00
Swamper	50.00
Swamper, one-half month	25.00
Man and team (half time)	50.00
Total crew	$305.00
Supplies:	
400 ft. ⅝-in. hoisting cable	$ 50.40
6½ gals. gasoline	1.60
3 gals. lubricating oil	3.75
5 lb. Hecla compound	1.25
595 gals. distillate, at 7.5 ct. per gal.	44.62
1 cylinder cup	3.00
Rollers	21.00
Large intermediate gear	14.00
172 lb. dynamite, at 16 ct. per lb.	27.52
1,000 ft. fuse	7.50
2 boxes caps	1.60
Depreciation of dredge ($5,000)	40.00
Total supplies and depreciation	$216.24
Total cost of excavation per mo.	$521.24
Total cubic yards excavated	14,941
Cost per cubic yard excavated	$0.035
Operation cost per hour (based on 255 hours)	$2.05
Operation cost per hour (based on 200 hours)	$2.61
Cubic yards excavated per hour (based on 255 hours)	58.6
Cubic yards excavated per hour (based on 200 hours)	74.7

An actual cost of 3.5 ct. per cu. yd. of excavation is very good under ordinary conditions, and especially low considering the fact that this cost includes excavation of hardpan and that the proportion of time lost in making repairs was abnormal. The customary contract price for moving surface earth with teams in this district has been about 8 ct. per cu. yd. where no hardpan is encountered, and the excavation of hardpan has cost as high as 50 ct. per cu. yd. Comparing this with the above figure of 3.5 ct. gives a decided advantage in favor of dredge operation where practicable.

The output was 747 cu. yd. per 10-hr. day for 20 days per month.

Cost of Excavating Drainage Ditch With a Dragline Excavator. Ray S. Owen, in *Engineering and Contracting*, Mar. 11,

1914, gives the following data regarding the cost of excavating drainage ditches in Rock County, Wis. The machine used was a dragline dredge with steam power, running on a track laid by hand and propelled by pulling on a dead man with the hoisting drum. The operating crew consisted of 1 runner, 1 fireman, 2 trackmen and 1 teamster.

The ditches are in a hay meadow, the soil being about 2 ft. of muck underlain by sand. The ditches averaged 5 ft. deep with 1½ to 1 slope, the main ditch, 2.60 miles in length, having a 6-ft. bottom with 21-ft. top and the lateral 1.36 miles in length, having a 4-ft. bottom with 19-ft. top. The total excavation computed for the ditch was 53,019 cu. yd. The soil caved very badly and a large amount of excess material had to be excavated to get the specified prism clear of dirt. The amount of earth actually moved was about 75,000 cu. yd.

The two ditches are not connected but empty into Sugar River at points about one-quarter mile apart. This arrangement necessitated a tear down and move of about three miles from the end of one ditch, after it was completed, to the other ditch, and a set up.

The costs given include freight on machine from Madison, Wis., to Sterling, Ill., the operation, moving, repair, etc., of the machine during the work, and the tearing down and delivery of the machine on board cars at Sterling, which is about 8 miles from the job. The rent of 2 ct. a yd. included the furnishing, by the owner of the dredge, of sheaves and cable, which was a large item as the sand wore them out very rapidly. The cost of coal, teaming and moving is rather large, because of very bad roads when the outfit was moved out in the spring and the deep sand through which the coal was hauled during the summer. The unit prices are given for the contract yardage and for the actual yardage.

	Contract yardage	Actual yardage
Rent of dredge	$0.020	$0.014
Labor	0.054	0.038
Coal	0.009	0.006
Express and freight	0.003	0.002
Bond and liability insurance	0.002	0.002
Livery and carfare	0.002	0.001
Oil	0.001	0.000
Teaming and moving	0.011	0.008
Tools, supplies, repairs, lumber	0.003	0.002
Miscellaneous	0.001	0.001
Total cost per cu. yd.	$0.106	$0.074

Electric Dragline Excavators on Drainage Work. *Electrical World,* Oct. 28, 1916, gives data for drainage work on the Boise

Project of the U. S. Reclamation Service in the vicinity of Caldwell and Nampo, Idaho.

Four excavators of the same type and capacity, having caterpillar traction, 50-ft. booms, 9.5-ft. swing circles and 1.25-cu. yd. buckets are used. They are designed to operate on 440-volt, three-phase, 60-cycle, alternating-current supply. The caterpillar drive and the drag drums of the excavators are driven by direct geared 80-hp. motors controlled by a drum-type controller provided with resistance, switchboard and circuit breakers. The swing machinery is operated by a 40-hp. motor provided with a drum-type controller for quick acceleration, designed to make it possible to reverse at full speed. The operating crew consists of two men for each excavator—the operator and an oiler.

The total drainage results accomplished on the Boise Project with the electric excavators to June 1, 1916, consists of the removal of 3,762,350 cu. yd. of material in approximately 93 miles of open ditches. The ditch sections vary from 10-ft. base 2 to 1 slopes, to a 5-ft. base 1.5 to 1 slopes, and the average cut approximates 10 ft.

At the field camp headquarters a substation is located which transforms the current to 4,000 volts. The transmission lines erected for the drainage construction carry 4,000 volts and are built and rebuilt as needed in the construction of the various drains. In the building of these lines, 30-ft. poles are generally used and No. 4 bare copper conductor. The connection from the transmission line to the other transformers which are carried on the dredges consists of No. 6 B & S gage triple conductor armored cable, and connection is made from the three wires of this cable to the transmission lines by hook switch terminals fastened on the ends of light 25-ft. poles. The connection is transferred from pole to pole as the construction proceeds, and the 300-ft. length of cable used allows the passing of obstructions.

The average energy used is approximately 0.88 kw.-hr. per cu. yd. of material excavated, varying with the material excavated, being as low as 0.39 kw.-hr. in light sandy loam including all line and transformer losses.

The use of power has been very convenient around the headquarters camp, where a machine shop is electrically operated to handle repairs and also for use in pumping water in the construction of culverts. Each excavator is lighted by two inclosed-type flaming arc lamps.

The approximate cost of excavation to date has been as follows:

Labor cost	$0.023
Electrical energy (at 1 ct. per kilowatt-hour) and supplies	0.019
Installing transmission and telephone lines and sub-stations, including cost of materials	0.013
Total per cu. yd.	$0.055

This is exclusive of depreciation and general expenses.

Drainage Canals Built by Dredge and Dragline. *Engineering News*, Feb. 20, 1913, gives the following: Over-use of water for irrigation having turned productive farms on the Yakima Indian Reservation, Washington, into swamps and barren alkali flats, a drainage system was constructed by day labor by the U. S. Indian Service.

The following are the detailed costs and construction data of the three machines used:

Marion Dredge—1-yd. dipper dredge, 40-ft. boom. Limit of dump above water 15 to 18 ft. Limit of digging below water, 12 ft. Center of hull to center of dump, 35 to 40 ft. Size of hull, 60 x 18 x 5½ ft. About 24,000 ft. B. M. lumber required in construction of hull.

Cost of machinery f.o.b. Marion, Ohio, $5,000. Cost complete with hull in working order about 8 miles haul from the railroad (exclusive of freight charges on machinery from Marion, Ohio, to Toppenish, Wash.), $10,034.

Started to excavate, Nov. 17, 1910, and worked steadily till Mar. 13, 1912, usually excavating in soft material with gravel subsoil and occasional streaks of hardpan. Results:

Total cu. yd. excavated	502,911
Total in. ft. of canal	57,944
Total 8-hr. shifts operating	823
Cost per cu. yd.:	
Field supervision, including clerical	$0.005
Labor operation	0.037
Hardware, tools, etc.	0.002
Repairs, shopwork, etc.	0.004
Camp maintenance	0.002
Coal, $4.85 per ton delivered	0.016
Cable	0.005
Oil, waste and carbide for lights	0.003
Total per cu. yd.	$0.074

No depreciation charges have been added, but it is believed that from 1 to 1½c. per cu. yd. would cover this item.

Dragline—This machine was constructed by the Washington Iron Works, of Seattle, Wash. It had a 50-ft. boom, with 1 yd. Channon bucket, operated by a 7 x 10¼-in. double engine. The machine was mounted on skids and hauled back by an independent

engine mounted on the rear. It was started in September, 1910, and finished on expiration of lease, Apr. 15, 1912.

The material excavated comprised volcanic ash with occasional streaks of hardpan that required blasting, underlaid with loose gravel.

Total cu. yd. excavated	539,235
Total lin. ft. of canal	68,590
Total 8-hr. shifts operating	917
Field supervision, including clerical	$0.006
Labor operation, including $225 rent per mo	0.060
Hardware, tools, etc.	0.003
Repairs and shopwork	0.011
Camp maintenance	0.003
Coal, cable, oil, waste, carbide for lights, etc	0.026
Total per cu. yd.	$0.109

Due to the layout of the canals, this machine moved empty about $2\frac{1}{2}$ miles, which expense is included in the above costs.

Lidgerwood Class B. Dragline Excavator—This machine complete for operation on the ground about two miles haul from railroad, exclusive of railroad transportation from Chicago, cost $11,555.

The material excavated comprised volcanic ash soil with occasional streaks of hardpan, underlain with loose gravel. The machine started to operate Oct. 1, 1910, and the data are given to June 20, 1912.

Total cu. yd. excavated	789,968
Total lin. ft. of canal	92,305
Total 8-hr. shifts operated	1,024
Field supervision and clerical	$0.005
Labor operation	0.035
Hardware, tools, etc.	0.004
Repairs and shopwork	0.013
Camp maintenance	0.002
Coal, cable, oil waste, carbide for lights, etc	0.023
Total per cu. yd.	$0.082

No depreciation has been charged in the above, but it is believed that about $1\frac{1}{2}$ ct. per cu. yd. should cover this item.

This machine moved empty, a total distance of about 18 miles, which expense is included in the above costs.

It may be of interest to note that the total amount disbursed, including engineering, structures, clearing, fence moving and inventory, which covers all depreciation, added to the excavation, shows a cost of about 12 ct. per cu. yd. when applied wholly to to the excavation.

Floating Dredges for Ditching. The methods and costs of floating dredge operation will not be treated at length here as a full discussion of this subject is given in Chapter XV. There

are a number of companies manufacturing dredges especially for ditch work. Almost all dredges used for this type of construction are either grab-bucket or dipper dredges, the latter being generally used.

While dipper dredges do not make as neat a ditch or one to as exact grades and slopes as many of the other types of machines, they have gained favor because they can be worked under all kinds of adverse conditions and in any sort of material, not excepting blasted rock.

In many sections of the country stumps and roots, as well as buried logs, impede the work of the machines. Any contractor who has worked through such ground knows what difficulties he has had to overcome. Sunken logs are a prolific source of trouble, especially when they are of any length, and more than half of the log protrudes under the banks of the ditch. A dipper dredge has been the only successful machine for such work.

A finished, well-sloped ditch, with a true grade and solid bottom without holes in it, and spoil banks in good shape with a sufficient berm between them and the ditch to prevent the material from sloughing back into it, is much to be desired, to secure cheapness of maintenance and to make the ditch do efficiently the work for which it is designed.

A very important feature of dredges is the spuds. A dredge is, as a rule, either equipped with vertical or bank spuds, or both. These are necessary to balance the boat and hold it to its work, especially in digging hard materials or in handling large logs or stumps. They also prevent the boat from being wrecked or sunk. They must be adjustable in case of sudden high water and also for receding water. If they cannot be adjusted in a reasonable length of time, delays occur that are expensive. Special attention should always be paid to the spuds both in purchasing a dredge and in operating it.

Clam-shell or orange-peel bucket dredges are used to a large extent in ditch construction. In both styles of these buckets different types are made for soft and hard digging. In both the clam-shell and orange-peel buckets, makers build a type to grapple boulders and stumps.

Ladder Dredge Used in Excavating a Small Canal. A. M. Shaw, in *Engineering News*, Aug. 14, 1913, gives a description of machines used in excavating ditches and small canals in Louisiana, and states that ladder dredges of the Menge type have been used on work of this kind. The manufacturers of this dredge state that in open swampy prairie land a ladder dredge can do twice as much work as where the soil contains much clay, as the clay sticks to the bucket and will not dump. Where stumps

or cypress roots exist in considerable numbers trouble is experienced.

A dredge used near New Orleans, with a hull 22 by 60 ft. and the ladder swinging to either side, cut a canal 35 ft. wide. The distance from center line of the boat to end of the discharge apron was 40 ft., and the velocity of discharge was usually great enough to cast the material about 10 ft. further. The ladder had 32 buckets of about 6 cu. ft. capacity each. The boiler was 50 hp. and the engine had two 11 x 16-in. cylinders. The cost of the dredge was about $10,000.

The average monthly output of the machine was 24,000 cu. yd. The coal consumption was 1.5 to 2 tons per shift of 10 hr. The cost of operating the machine on a single shift was about $650 a month, giving an operating cost of about 2.8 ct. per cu. yd.

Cutting 1 to 1 Slopes With a Dipper Dredge. *Engineering News*, Oct. 19, 1916, gives an account of drainage work on the Little River Drainage District in Missouri. The ditch system involves 625 miles of dredged channels containing 34,250,000 cu. yd. of excavation. The ditches range in size from 4 ft. bottom width and 8 ft. depth, to 123 ft. bottom width and 12 ft. depth.

All work is done by floating dipper dredges, with bank spuds for the smaller, and bank or bottom spuds for the larger machines. The laterals are cut mainly by dredges with 1-yd. buckets. For the main ditches a 1-yd. dredge makes two pilot cuts 6 ft. deep, one on each side. These are about 22 ft. wide on top and 12 ft. on the bottom, with the 1 to 1 slope on the outer side. A larger dredge first extends each pilot cut to the full depth, and then takes out the center. In this way five cuts are made for the complete section. On the ditch with 123 ft. bottom width a dredge with a 4-yd. dipper has made a record of 83,278 cu. yd. in 26 working days.

The contract states that the completion of the work within the time is of special importance. With this in view it is specified that any contractor, before beginning the erection of a dredge, must obtain the engineer's approval of its size and capacity. This is required in order to prevent the use of dredges of insufficient capacity to make the desired progress.

The specifications provide that the work is to be staked out in advance by the engineer, to show the exact location and width of right of way, the ditch, the berm, and the levees. The depth of cut for a ditch and the height of fill for a levee are to be marked on the stakes.

The cutting of small ditches to greater widths than those specified (in order to admit floating dredges) may be done under certain conditions. The specifications provide that when the prism

is not of sufficient width to accommodate the dredge installed, the necessary width shall be obtained when possible by flattening the side slopes. Increasing the prism of ditches is permitted, subject to the approval of the engineer, but the increased prism must conform to the specified section (except in area), and payment is made only for material within this section.

In moving dredges from one piece of work to another it may be necessary for one contractor to pass over work which has been let to another contractor but has not been constructed. In such cases the former makes a cut sufficient for the passage of his dredge and is paid for this on the basis of volume actually removed at a price ½-ct. per cu. yd. below that of the contract price of the other contractor. The ½-ct. deduction is paid as compensation to the latter.

Dredging Ditches with 1 *to* 1 *Slopes.* A specially interesting feature of the work is that by the specifications the dredges are required to finish the cuts with 1 to 1 slopes. On ditches of this kind the usual practice is to excavate them to practically a U-shape, and let the sides cave in. This results in rough cuts and obstructed bottom.

Some trouble was experienced at first in getting the dredge men to do the work as required, but after a little explanation and requiring them to go back and dress the work not properly finished, they soon came to understand how to get the desired results. This is accomplished by taking a succession of light cuts on each side in such a way as to approximate the 1 to 1 slope, and then to excavate the center or core.

The diagram issued for instruction as to this slope cutting is shown in Fig. 21. The prism is cut by digging the corners first and working to the center. It is especially insisted that light cuts must be taken in digging the corners, as indicated on the cross-section. The roll from the berm is cleaned on completion of the fifth round.

Cross-Sectioning and Progress Records. The cross-sectioning of the ditches is done by sounding, taking measurements at the top, middle and bottom of each slope, and at 5-ft. intervals on the bottom for large ditches and 3 ft. for the small laterals. Instead of entering the figures in a book to be plotted later, the diagrams are plotted directly upon sheets of thin section paper, 17 x 10-in., clamped to a stiff board, the vertical and horizontal scales being 1 in to 10 ft. This eliminates much of the office work, and blueprints from the diagrams are very useful and effective in showing the contractors just what results they are getting and how these may be improved.

Typical diagrams from these plotted cross-section sheets are

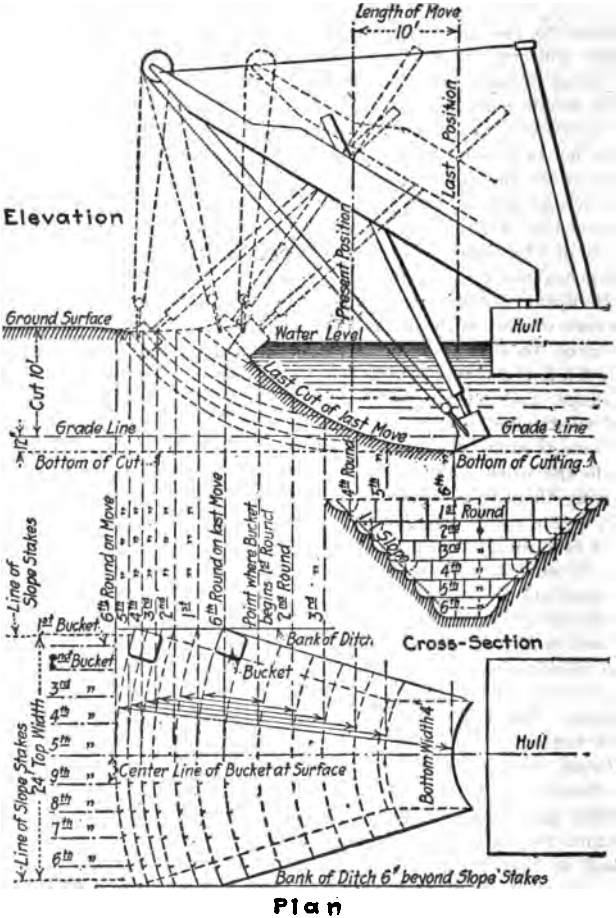

Fig. 21. Diagram Showing How to Dredge Ditches With 1 to 1 Slopes.

shown in Fig. 22, for both the large and small canals. These indicate the character of the actual excavation and the closeness with which the channels can be excavated to the theoretical section. In the smaller ditches the bottom is invariably concave instead of flat, but soon fills up practically to the grade line.

Dredging Canals on a Drainage Project in Louisiana. *Engineering and Contracting*, Oct. 25, 1911, gives the following: The project here described is one of a great number now under

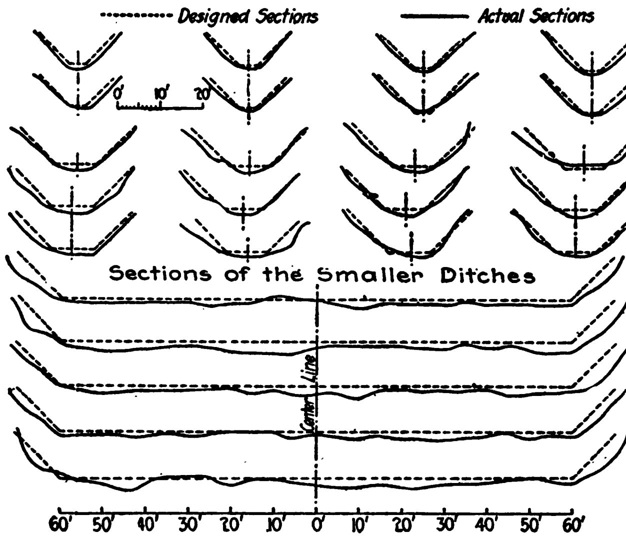

Fig. 22. Typical Ditch Cross-Sections Obtained With Dipper Dredges.

way in the section near New Orleans. The two classes of land which are being reclaimed are the cut-over timber lands and the untimbered swamp lands. The timber lands cost considerably more to put into condition than do the swamp lands, because the heavy roots make the use of dredges impracticable.

The method of drainage is as follows: The 2,850-acre tract is enclosed with a canal known as a dredge boat canal, the earth being thrown on the outer bank to form a levee which is smoothed down to make a road or driveway. When this canal and levee

are completed two other large canals are dug at right angles to each other crossing the tract in each direction. See Fig. 23. These are for use for storage, to provide a large surface for evaporation, and essentially for the small lateral ditches to drain into. These lateral ditches are usually placed about 200 ft. apart. They are 3½ ft. deep, 4 ft. wide on top and 18 in. wide at the bottom. They are being dug by means of Hill ditching machines. The water is disposed of by a pumping plant designed to care for the maximum amount of rainfall, and stationed at the most convenient point for discharging water over the levee. The land in this district is composed of the material known as "sharkey clay," which is the sediment carried by the Mississippi River from the soils of the states through which it flows. This has been deposited here and gradually covered with a top soil composed of decayed vegetable matter. The soil is very rich and is not difficult to handle. The cost of reclaiming these tracts as based on the contract price of a number of 3,000-acre units is estimated by the engineers to be about as follows: For building levee and outside canal all round the tract, $8 per acre; for reservoir canals of sufficient capacity to care for runoff from maximum rainfall, $7 per acre; for lateral ditches, $2 per acre; for pumping plant, $2.75 per acre; for engineering and superintendence, $2.25 per acre; for incidental expenses, $2 per acre, making a total of $24 per acre.

The main drainage canal has a section 40 ft. wide on top and is 8 ft. deep. The main laterals are 18 ft. wide and 7½ ft. deep and the ditches are 4 ft. wide and 3½ ft. deep. All are made with banks at a natural slope. The general elevation of the ground is about 5 ft. above sea level. A pumping plant is under construction near the southeast corner of the tract.

The excavation of the main canals was begun in the latter part of 1909 and was prosecuted almost continuously until the completion in August, 1911. This work was carried on by means of two Marion dipper dredges, one with a ¾-cu. yd. and the other with a 1½-cu. yd. bucket. The large dredge was on the ground when the work was begun and the small one was built afterward at a cost of about $8,500. Two oil barges of about 400 bbls. capacity each were built to carry fuel oil for the dredges from New Orleans. All supplies had to be brought in on barges. One 25-hp. gasoline tug was used for all towing.

The cost figures were taken from the company's books, with the exception of the charge for plant. This is an arbitrary figure based on an estimate of 25% depreciation of the plant for the two years' work. The small dredge was new and was built on the

site. The other dredge was used on previous work in the vicinity. The plant is taken as worth $20,500 at the beginning of work. The labor charge is taken from the payroll account and includes

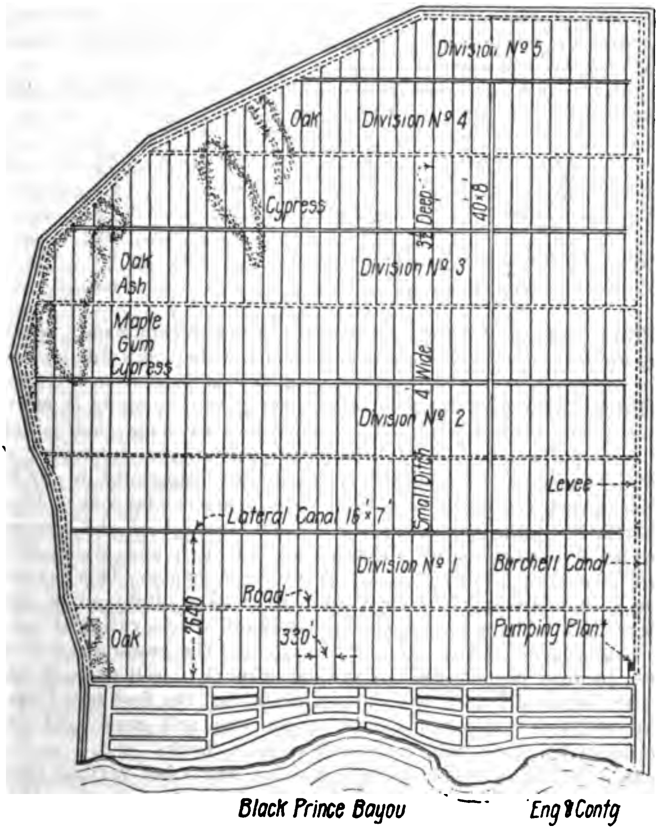

Fig. 23. Plan of Drainage Canals and Laterals for Reclaiming Louisiana Swamp Land.

all labor charged to the contract, such as dredgemen, camp labor, clearing, towing, superintendence, etc. The supplies include all supplies except camp supplies. The repair account includes all repair parts and freight on same, but does not include the labor

for making repairs. The general expense account includes all expense not included in other accounts, such as taxes on plant, traveling expenses, railway fares of men, office expenses, etc. No interest is included. The fuel account includes only the oil used for the operation of the dredges. The rates of wages paid were for common labor $2 per day, engineman $125 per month, crane-man $65, fireman $50.

The rates of the monthly men include board in addition. The costs follow:

Plant (arbitrary)	0.8
General	0.6
Repairs	0.2
Supplies	1.4
Fuel	0.9
Labor	2.2
Camp	0.8
Total ct. per cu. yd.	6.9

These costs are for the excavation of the main canals only, totaling 675,000 cu. yd. The work of excavating the small ditches and the construction of the pumping plant are at present under way.

Ditch Excavation by Natural Erosion. It is a waste of effort to cut some ditches to finished lines and to slope their sides. This is particularly so of ditches cut for stream diversions in connection with the building of railroads, especially in undeveloped sections of the country. Many engineers lay out a ditch of relatively the same size as the old channel of the stream, sloping and dressing up the sides of the ditch and giving it a fair gradient. This is usually a waste of money. If a stream has a channel varying from 6 to 8 ft. wide a ditch can be dug about 3 ft. wide, say wide enough to admit of excavating it with a drag scraper, and its sides left vertical. The grade given to it need be very slight. Then if the old channel is well drained, the water will be diverted into the new ditch, and the first heavy rain will excavate the ditch to its proper size and grade and the action of the water and frost will slope its banks.

In diverting a stream in Arizona that had a bed varying from 25 to 30 ft. in width, a ditch was laid off just wide enough to take a Fresno scraper, namely, from 4 to 5 ft. wide. The excavation was done with these scrapers at a low cost, the banks being left vertical. The grade was such that the water dammed up quite a little before it ran through the new ditch, but the first rains washed out a new channel about as wide and deep as the old one. However, this plan can not always be followed when the country is well settled and the land is valuable, for then it may be necessary to keep the stream under control.

Ditch and Canal Excavation by Sluicing. Canals and ditches may be excavated very cheaply by first digging a narrow, shallow passage-way for the stream, and allowing the water to bring the ditch to its full width and depth by erosion of the banks and bottom. Very large waterways may be excavated in this manner. The chief disadvantage of this method lies in the difficulty of controlling the course of the stream. Water naturally washes away the softest materials, and the course of a ditch dug by this method will probably be very crooked. The direction may be controlled in some measure by plowing and loosening the earth as the water attacks it, as was done in the cases hereafter described. This method is then very low in construction cost but wasteful of land, and should therefore be pursued only where the value of land is low.

Prof. B. M. Hall, in the *Engineering Annual*, University of Georgia, Vol. I, 1893, gives some data on sluicing methods used in swamp reclamation in Charlton county, Georgia. This swamp was a shallow, fresh-water lake, covering 400,000 acres, and filled with black muck. To drain it a narrow, shallow canal was cut through a ridge intervening between it and the river, at an elevation 20 to 25 ft. above the proposed bottom of the permanent canal. This shallow canal was constructed by teams and scrapers. It was 17 ft. deep at the summit of the cut. To widen and deepen it a stream of water was pumped from the swamp, and a "porcupine" harrow (a round log filled with harrow teeth) was dragged up and down the canal a distance of 1,000 ft. at a time by steam power. The pumping plant consisted of two 80-hp. boilers and two 14-in. centrifugal pumps, lifting 30,000 gal. per min. The cost of excavation was only 2.5 ct. per cu. yd.

The method used for draining the Okefinokee Swamp was also successfully pursued in excavating a canal near Laramie, Wyo. The methods and cost of the work are given by Lyman E. Bishop in *Engineering News*, Sept. 9, 1911, as follows:

The work was the construction of part of an 8-mile canal joining the Big Laramie River to Lake Hattie, a part of the Laramie Water Co.'s irrigation project. The first 7 miles of the canal were built with dragline excavators during 1910. The grade of the canal was 0.02%, the bottom width was 40 ft., and the depth of water, 8 ft. Between the end of the excavated portion of the canal and Lake Hattie, a distance of 6,000 ft., there was a drop of 70 ft. The plan of excavating this section by sluicing was feasible, there being a grade of 1.15% and 1,000 cu. ft. of water per sec. available. Practically all of the material was disintegrated feldspathic red granite, the coarsest particles

of which were of fine uncemented gravel, the largest sizes passing through a 1-in. ring. Some large boulders were present. After the channel had been washed out to a depth of 25 ft. a shale stratum was uncovered. This rock and the large boulders that were washed from the fine material and practically covered the bottom of the ditch, prevented further erosion. It should be noted that there was a large unavailable capacity in Lake Hattie below the outlet culverts, and this space could contain the material sluiced from the canal. The section shown in Fig. 24 was excavated by teams under a contract. This small ditch contained 7,100 cu. yd. It was completed in 17 days. The cost was 20 ct. per cu. yd.

To assist the water in its erosive action in cutting away the upper bank the following added provisions were taken: A steel blade 18 in. long, 6 in. wide and sharpened on one edge, was securely attached horizontally to the beam end of a No. 5 railroad plow. With the plow in the lower corner of the bottom of the ditch this blade extended about 9 in. into the side of the ditch,

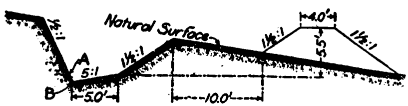

Fig. 24. Section of Canal.

as shown by the dotted line at *A*. A light furrow was plowed throughout the entire length of the finished ditch at the point *B*, and at the same time a 9-in. cut was made in the side, as shown at *A*. It is believed that the sloping bottom of the ditch and the cut in the upper side were very valuable factors in the final success of the sluicing method. At the time the first water was turned in the ditch its tendency was to hug the upper bank and undermine it, the upper bank caving off from above, while very little erosion took place on the lower side. Practically all the erosion has been on the bottom and upper side.

About 200 second-ft. of water were turned into the ditch the first day, and approximately 100 second-ft. additional each succeeding day. At the end of 9 days the channel at the lake end was 40 ft. wide by 25 ft. deep, and at the upper end it was 30 ft. wide by 8 ft. deep. Some sluicing took place in the previously finished section of the canal, the washing extending back a distance of 800 ft., with a maximum depth of 8 ft. at the sluice ditch end. The total yardage washed out in 9 days was 85,000 cu. yd. Assuming that an average of 600 second-ft. ran through

the sluice ditch during that period, then 200 cu. yd. of water were required to excavate 1 cu. yd. of earth.

The cost of the sluicing was practically nothing. If we divide the contract cost of the work done with teams $1,420 by the total yardage moved (92,100 cu. yd.) we have a cost of the sluiced canal of approximately 1.5 ct. per cu. yd.

Railroad Ditches. Ditches in long and deep railroad cuts are not only expensive to make, but also to maintain. The long haul of the material makes the building expensive, especially with team, when the ditches are excavated before the track is laid. The work is generally done with teams and scrapers. After the track is laid it is very difficult to use scrapers in cleaning the ditches. For this reason there have been various devices invented for cleaning and maintaining ditches through railroad cuts. One is a scraper used with a locomotive or car, the plan being either to drag the material into piles, to be afterwards loaded on to cars, or else drag it to the end of the cuts. Another device is a wing scraper fixed to a car, operated like a road machine. Although these cheapen and hasten the work, yet, as they do not load the material, they have not been an unqualified success.

Railway Ditchers. A number of engineers of maintenance have invented scraper or dipper machines that they have had built in the shops of the railroad company for this class of ditch work, and very efficient work has been done by such devices. To-day there are several such machines made by the manufacturers of excavating apparatus.

The Browning Engineering Company of Cleveland, Ohio, makes a light locomotive crane mounted on a low set of wheels for this purpose, and the Marion Steam Shovel Co., of Marion, Ohio, mount one of their light shovels in the same manner.

A train of flat cars is used for the work. Two sections of light rails, from 20 to 35 ft. long are laid down on the cars and the locomotive crane equipped with a dipper, or a small steam shovel is placed on this track. The dipper is used to excavate the material from the ditch, loading it directly on the flat cars. As the cars are loaded the machine travels along on the track on top of the cars. The section of track is picked up by the machine and carried from the rear to the front. The machine works on both sides of the track on a single track road. Where there is more than one track, the train first works on one side of the cut and then goes to the other.

Either light or heavy work can be done in this manner economically, and a long stretch of ditch can be made or cleaned out in a day. In heavy work the excavator is moved as the cars are loaded, while in light work the whole train is moved by the

locomotive. In this manner a full load can always be placed on the cars. After the train is loaded it is taken to some embankment and the material used to widen or place a shoulder on the fill, or else it is dumped through some trestle that is being filled. This is also one of the economic features of cleaning railroad ditches out by this method.

Another consideration is that a larger ditch is dug by these machines, so it is not necessary to clean the ditch frequently. Then, too, since the material is carried out of the cut it does not wash back during rainstorms as is the case when the ditches are cleaned out by hand and the earth is thrown on the side of the ditch. These revolving shovel ditchers can also be used to pick up slides that result from heavy rains and the action of the frost.

The American railway ditcher (Fig. 25) is a small revolving shovel primarily designed for digging railroad ditches. It may also be equipped as a locomotive crane with orange-peel or clamshell bucket, with pile driving leads, with a car unloading device, or it may be fitted with a derrick boom for loading logs or for laying track. It has four center-flanged wheels for use on portable track sections of two widths, thus eliminating the necessity of having bolted rails for it to travel upon. It is also equipped with four standard gage wheels. The track furnished with the machine is made up of two portable track sections, enabling the machine to travel over flat cars of unequal height. The engine has three drums: One for the hoisting line, one for the pull-in-line, and one for the line that controls the height and radius of the boom. The depth of cut is regulated by raising or lowering this boom. An unique device furnished with this machine is the plunger at the end of the boom. This plunger enters the bucket when the latter is about to dump, and acts as a ram, forcing out sticky material. The machine has a full circle swing. When mounted on a car it is within the clearance limits of railroad structures.

The pre-war prices of the machine (including services of erector) were as follows:

Complete ditcher	$5,950
Extra for clam shell bucket attachment	100
Extra for scraper bucket attachment (29.5-ft. radius)..	
Extra for car unloading attachment (pusher scoop)...	385
Extra for 30-ft. pile driver leads and 1,500-lb. hammer	425
Extra for 40-ft. leads	100
Extra for 2,000-lb. hammer	25

Cost of Operation of American Ditcher. The cost of hand ditching on the C. R. I. & P. Ry. in Nebraska was as follows:

Fig. 25. American Ditcher Removing a Slide.

67 laborers @ $1.35	$90.45
1 foreman	2.75
1 timekeeper	2.50
Total for 144 cu. yd. of ditch	$95.70
Cost per cu. yd.	0.665

The cost of ditching with the machine was as follows:

1 engineman	$ 4.00
1 fireman	2.00
2 section men @ $1.50	3.00
1 ton of coal	2.00
Oil, waste, repairs	0.50
Depreciation and interest at 18% on $6,000 over 150 days per year	3.00
Total for 264 cu. yd.	$14.50
Cost per cu. yd.	0.06

This does not include train service.

The cost of operating a ditcher on the Illinois Central System during December, 1906, is given below. The machine handled wet clay, sand and gumbo at the rate of 15 cars of 21 yards each (loose?) in 4 hr. 15 min.

	Ditcher crew	Train crew
1 engineman	$ 5.00	$ 4.00
1 fireman	2.50	2.00
1 conductor		4.00
1 flag man		3.00
2 laborers	2.60	
Coal and oil	2.75	12.0
Total for 315 cu. yd.	$12.85	$25.00
Cost per cu. yd.	0.04	0 12

The average quantity handled by this machine under average conditions is from 4 to 5 cars of 12 to 15 cu. yd. each per hr.

A railroad running into Chicago made the following record in 1914; 51 dump cars, holding 765 cu. yd. of very hard blue clay were loaded in 7 hr., at an average cost, including train crew, ditcher crew, coal, oil, etc., of 4.9 ct. per cu. yd. In 31 days 18,000 cu. yd. were loaded at an average cost, including a 9-mile haul to dump, of 10 ct. per cu. yd. 25 ct. per cu. yd. was the price for steam shovel work on the same job.

Ditching on the Southern Railway. *Engineering and Contracting*, May 20, 1918, states that the greater part of the right of way ditching on the Southern Ry. was done by American railway ditchers. On a recent job one of these ditchers, working in rocky soil where the digging was very hard, took out of the ditches and dumped an average of 623 cu. yd. per day for a period of 25 days. On the first day work was commenced at 6 a. m. and stopped at 4:30 p. m. Train service held up the digging for 2 hr. and another hr. was consumed taking on coal and water,

leaving 7½ hr. of actual working time. In this time 704 cu. yd. of material were taken out of the ditches, deposited on a fill and leveled off with the spreader. On this day 1 ton of coal, 1,200 gal. of water, 1 qt. of oil and 1 lb. of waste were used in the operation of the ditcher.

The following table shows the work accomplished in one month:

Hours on line	308¼
Operation delays, hours	83
Time worked, hours	159½
Cars loaded	970
Total cu. yd. loaded	15,520

The cost of the ditching crew per day was:

Operator	3.34
Fireman	2.16
Two laborers at $1.55	3.10
Total	$8.60

This makes $224 for the 26 week days worked, or 1.5 ct. per cu. yd. for loading only.

On this particular work the American railroad ditcher was used between two dump cars, which were dumped by hand, there being a laborer on each car for this purpose. These two men also handled the spreader car. On other ditching work on the Southern two and sometimes three ditcher dump car work trains are used.

Ditching with an Electrically Operated Ditcher. *Engineering and Contracting*, Jan. 15, 1919, abstracts the following by Charles W. Ford, from the *Electric Railway Journal.*

On the Kansas City, Clay County and St. Joseph Railroad, a 78-mile electric line, an American railroad ditcher was placed in operation in 1915. The ditcher has a 20-hp. motor and operates on 1,200 to 1,500 volts. It was the first electrically operated machine of this type to be built. The ditcher is mounted on a specially constructed flat car 50 ft. long and with a capacity of 100,000 lb. The ditcher travels back and forth on the car on two sections of 100-lb. A. S. C. E. rails, this being necessary in order to permit the flexibility of forward or backward motion when loading the shovel or, if the material is to be hauled, when unloading into dump cars placed in front of the ditcher. A great amount of the material that is necessary to handle out of the ditches is a grade of clay which is exceedingly difficult to dig when dry, and is about the stickiest substance extant when wet. Rock and shale are common in the cuts along the line and a few years ago slides were not uncommon in wet weather. In most instances the material taken from the ditches and the cuts is de-

posited on fills, but in shallow cuts the material taken from the ditches is in many cases deposited on the surface of the sides of the cut, thus providing an embankment which takes the place of surface ditches. This operation, which is much more rapid than is the use of dump cars, eliminates the haul entirely. The dump cars are of the side-dump type, holding 20 cu. yd. and are operated by air, the entire train being hauled by an electric locomotive.

During 1918 it was necessary to use the ditcher for a period of only two months, and for the 60 days from May 1 to July 1, 1918, the following figures covering an average day's work have been compiled:

Work: Right-of-way ditching, cut widening and bank filling.
Material: Clay, fairly dry and tough, with some stone and shale
Length of day: Fourteen hours.
Time actually working: Seven and one half hours. (This includes the time consumed in ditching, dumping, traveling to and from the siding, clearing for trains.)
Crew used: Operator and two laborers: Train crew: Motorman and conductor.

Daily Cost:	
Payroll	$23.52
Power	5.00
Oil, waste and repairs	2.50
Incidentals	1.26
Total	$32.28
Average daily yardage, cu. yd.	225 6
Cost per yard, ct.	14.3

Fig. 26 shows the unit cost for different lengths of haul.

A Ditching Car with Plows and Scrapers. *Engineering News*, May 7, 1896, describes a car equipped with plows, mold boards, scrapers, and excavator or ditching scoops, as used in 1895 on the St. Louis Southwestern Ry. This machine consists of a flat car, on which is mounted a compressed-air operated crane, from which are hung the cutting and loading devices. The method of working consists in cutting one or two furrows, 20 in. deep by 36 in. wide, with the plow, then using the scraper to bring the earth from the ditch up toward the track, or to throw it up and away from the track as desired. and finally to trim off the excavation with the mold board. The ditching scoop is used in deep cutting. It is filled in the manner of a drag scraper, hoisted up, and dumped when the car has been run to the dumping place.

The force required consists of 1 conductor, 2 brakemen, 1 airman, and 2 laborers, costing $18.30 per day. A locomotive is required for pushing the car, bringing the total cost up to about $30 per day. Under favorable conditions 1.5 to 2 miles of ditch and embankment were dressed in a day.

The Bowman Ditcher. *Engineering News*, Jan. 20, 1910, gives the following:

This machine (Fig. 27) is designed for constructing or cleaning railroad ditches. It consists of a car carrying four pneumatic cranes (two on each side) for handling plows, scoops, slopers, and spreaders, air cylinders, air reservoirs, and three Westinghouse compressors. Steam for the compressors is supplied by the attendant locomotive. In operation, the ground is

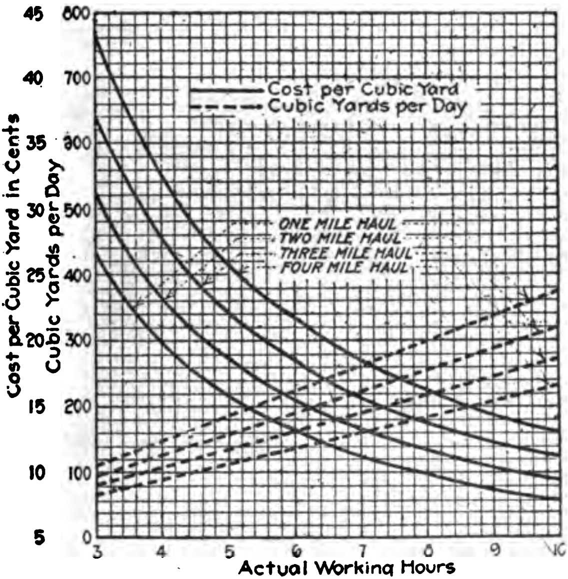

Fig. 26. Cost Diagram for Electric Ditcher.

first broken up with a special heavy plow, drawn at the end of an arm, by the car. The scoops are then put in position and pulled through the loose material. These scoops each hold 4 cu. yd. Fig. 27 shows the machine with both scoops loaded, one having been hoisted to the carrying position. The filled scoops are lifted to this position by the cranes, and the locomotive tows the ditcher to the dumping place. When necessary the dumped material is leveled off with the spreader. The ditcher is then returned to the cut and makes the final slope of the bank with the sloper. The process is repeated if necessary. On one

section of the Southern Pacific R. R., where an average travel of 1,200 ft. only was required from cut to dump, in hard sun-baked soil, a total of 600 cu. yd. was removed in 6 hr. This was done in 30 loads.

Highway Ditches. Not only should wagon roads always have ditches on each side of them, when the road goes through a cut, but these ditches, to serve their purpose, should be kept clean. To do this work by hand is quite expensive, so whenever possible other methods are used.

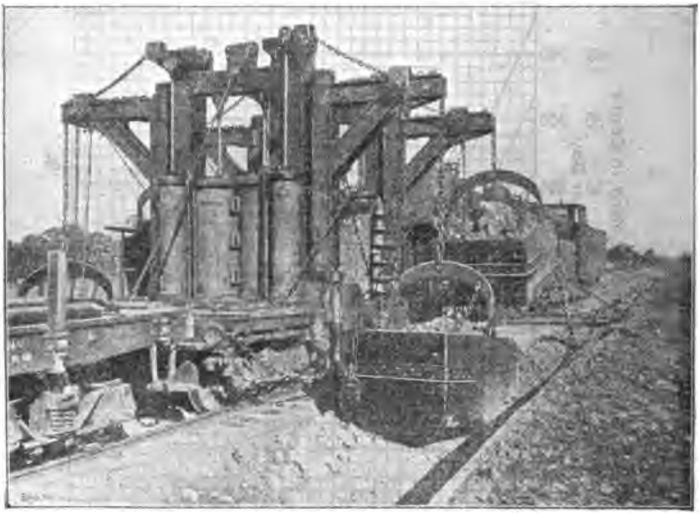

Fig. 27. The Bowman Ditcher.

The large four-wheeled road machines are useful for this purpose and well adapted to the work. They are used not only to shape up the road, but also to cut out the V-shaped ditches and to maintain them.

Besides these four-wheeled road machines there are on the market a number of two-wheeled road machines or graders as they are frequently called.

There are also other small graders meant to be drawn by two horses, but instead of being mounted on wheels they are dragged on the ground. Some 10 or 12 firms make graders of the above kind and they can all be used in ditch work. When the material

is soft and wet road drags can also be used to clean out ditches along wagon roads, and the ditch can be made to conform to the crown of the road.

See Chapter IX.

Gopher Ditches. *Engineering and Contracting*, Sept. 13, 1916, gives the following:

Many miles of "gopher ditch" (Fig. 28) have been constructed for sub-drainage in Southern California. It has the advantage over open ditches that no land is taken from cultivation and no barrier is formed to free travel for agricultural operations. It calls for less investment than tile drains. Its disad-

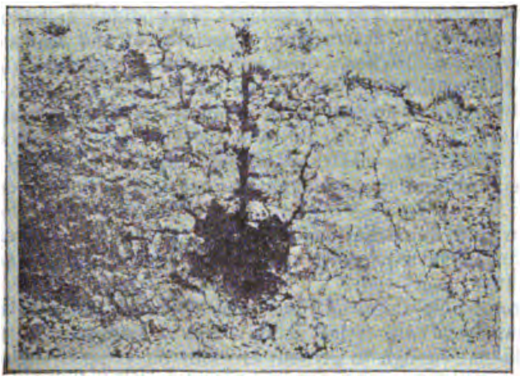

Fig. 28. A Gopher Ditch for Land Drainage.

vantage is the possibility of complete closure by caving. A short life would also seem to be natural, but it is stated that it has been found that gopher ditches will give service from 5 to 14 years, depending upon the character of the ground.

The construction of gopher ditches requires special machinery. At the Santa Ana Sugar Co. farms the outfit comprised a special gopher ditch plow and three Holt caterpillar tractors for hauling the plow. The plow is the special tool. It consists of a strong carriage, which rides on the surface and carries, projecting downward, the plow proper, which can be raised and lowered by suitable mechanism. Attached to its heavy framework is a single knife-blade beam, thin enough to avoid any great disturbance on the surface of the soil, yet wide enough to give it strength for withstanding the terrific strains to which it is subjected. The construction of this part of the tool is very similar to that of a

subsoiler. At the point, however, there is attached a torpedo-shaped affair, made of steel; this is the gopher.

In operation, the gopher is run down 4 ft. below the surface of the ground and is then pulled straight forward. The plow used by the Santa Ana Co. had a gopher 8 in. across, so that it made a drain ditch 8 in. in diameter. The point of the gopher is so shaped that, as it is forced through the ground, it spreads the earth evenly to all sides of it, packing it tight and making a solid, smooth-faced closed ditch.

Maintenance of Ditches and Canals. The proper maintenance of drainage canals and irrigation ditches is second in importance only to their construction. Banks are washed by rain or undercut by the current. Too steep slopes cause slides, and burrowing animals aid in the destruction, especially of the banks of elevated irrigation ditches. Channels become clogged with weeds and débris so that the velocity of the stream is decreased and material washed from the banks in one place is deposited as silt in another. Thus in time uncared for channels become entirely clogged. While this matter is of chief interest to irrigation and drainage engineers it should not be overlooked during construction.

Design and Construction of Ditches to Reduce Maintenance. E. H. Cowan, in a paper before the Ill. Soc. Engineers and Surveyors, 1910, said:

In establishing the grade line of a ditch the ideal to be aimed at is a uniform rate of fall from source to outlet. The gradient should be flat enough to prevent erosion, yet steep enough so that at times of maximum flow loose material which has settled into the bottom of the ditch will be washed away. This ideal gradient can very seldom be used, on account of other rigid determining conditions, but the nearer it can be approached the better.

Humps in the grade line can not be considered objectionable from a maintenance standpoint, but sags are very objectionable and should be avoided wherever possible. It is a great mistake to break up the grade line into short sections for the purpose of saving a small percentage of yardage, except in the somewhat rare case of the ditch being through soil which will not erode under the most extreme conditions, because if a stream of water containing suspended matter passes down a ditch over a sag to a flatter slope, the coarser particles will be deposited, and the ditch will give trouble at that point. For the same reason curves should be as flat as possible, in order that the velocity of the water may not be checked and deposits occur.

In designing ditches, maintenance requirements should be constantly borne in mind. Narrow bridge openings cause more or

less filling due to eddies which are formed. Concrete bridges should not be used where the channel is to be kept clear of silt with a dredge, unless they are high enough for the dredge to pass under. Outlets for tile drains and smaller ditches should enter the main ditch at an acute angle to prevent erosion at these points.

If ditches are gone over every year, hand and team work will be likely to be principally relied on. The former is to be preferred, even in places where the cost would be considerably greater, for the reason that the dragging of scrapers up the banks harrows them up and leaves much loose material on the slopes which will be washed back in by the next rain. The writer once undertook to clean out a narrow, deep canal leading to a water works intake. Each year or two during the previous 10 years this canal had been cleaned out by teams and scrapers, but it would soon fill in again. The method the writer used involved the lifting of the scrapers out with a derrick, thus not disturbing the slopes, and the result was that the canal stood at least 6 years without any further repairs.

E. E. Watts, in a paper read in 1902 before the Indiana Engineering Society, estimated that the expense of maintaining a 10-mile ditch running 25,000 cu. yd. per mile, in operation 5 years, need not exceed $10 per mile per year. This is a very small amount compared with the benefit to be obtained from keeping the ditch always in good condition.

Grades Required for Self-Cleaning Ditches. G. P. Smith, in a paper before the Iowa Engineering Society, Jan. 1912, said:

The proper construction and the proper maintenance after construction of open-drainage ditches is a subject for the serious consideration of drainage engineers. If sufficient velocity or volume of flow can not be procured to give the water a silt-carrying capacity, we know that the silt will inevitably lodge in the channel and eventually fill it. When we have not the available fall and know that the water will deposit siltage, our greatest efforts must be to see that the drain is so constructed and so protected as to prevent earth from caving or being washed into the channel.

Levels were taken in Webster County, Iowa, in 1909 over some 60 miles of ditch that had been constructed in 1905 and 1906. These ditches had bottom widths varying from 4 to 26 ft., grades from 1.5 to 10 ft. to the mile, and were all supposed to have been constructed with 8-ft. berms and 1 to 1 side slopes. They generally had a minimum cut of approximately 7 ft.

The levels on the mains, where the area drained was some 16,000 to 18,000 acres or over, showed that the ditch was self-cleaning with a fall of 2 ft. to the mile. On one main outlet drain with a tributary watershed of some 28,000 acres, the drain had

been deepened a few inches by the erosion. The fall was 2 ft. to the mile. We found that drains with tributary sheds of about 2,000 acres were not self-cleaning at less than about 5 ft. to the mile. With flatter grades and the same size drainage area the siltage rapidly increased, till at grades of 2 ft. to the mile we found an average of 2 ft. of siltage, and with 1.5 ft. to the mile as much as 3 ft. of filling in the drains, thus nearly destroying their usefulness. A 4-ft. grade required some 4,000 acres before it became self-cleaning. A 3-ft. grade did not seem to be self-maintaining with a shed area of less than 6,000 to 7,000 acres.

Necessity for Adequate Depth in Drainage Ditches. Richard L. Longshore, in *Engineering Record*, Feb. 21, 1918, gives the following:

Adams County, Indiana, with a total area of 337 square miles. is distinctly a farm county. More than 96% of its entire area is in farms and more than 75% is under cultivation. Of this cultivated area fully 80% is dependent on artificial drainage. The clay and heavy black loam soils of the county reach the highest productiveness only when thoroughly drained by means of drain tile.

The accepted standard for farm drainage systems is a line of 4-in. tile every 66 ft. These tile are laid in 24- to 30-in. trenches drained into 8-in. tile at a 30-in. depth. These 8-in. tile follow the natural depressions and water courses of the land, running either into a county or community drain. These outlet drains are being tiled up to and including 30-in. pipes. The average depth of such drains ranges from 4 to 16 ft. For drains above this size open ditches are used. These ditches flow into creeks or natural streams. Since the slope of most of these streams is between 1 and 2 ft. per thousand. it is nearly always necessary to open and improve the channel throughout the entire length. The farmer at the source of a drainage system is thus often interested in the construction and maintenance of 10 to 20 miles of drain.

The first open ditches were constructed from 3 to 6 ft. in depth and of sufficient size to carry surface water only. With the extensive subdrainage of the land it has become necessary to reconstruct these main outlet drains with sufficient depth and capacity to take care of the new subdrainage. During the last three years county drains have been built under the direct supervision of this office as follows: 36 miles of outlet open drain, comprising three main lines, 14, 12 and 3 miles in length and two branches of 3 and 4 miles in length. The bottom widths of the channels range from 6 to 16 ft. and the depths from 8 to 14 ft. In designing these drains depth was considered first of all. Eight

feet was adopted as the minimum depth and a channel was then designed sufficient to carry 50% more than the maximum runoff as computed from available data.

Two reasons may be stated for maintaining this minimum depth of 8 ft.

(1) The average depth of lateral tile outlet drains at the junction with the open ditch is 6 ft. Freezing is very destructive to a tile system with stagnant water in the pipes, especially at the outlet, where the drain is open to the air. Therefore the open drain must be at least 2 ft. deeper so that the entire tile system may drain off and be completely dry before hard freezing. When the breakup comes in the spring it is important that the open drain be deep enough to carry all surface water so that the water level is below the tile before the subdrains begin to flow. The subdrains must carry off practically all stored rainfall from December to April, besides the heavy spring rains, inside a few days. A difference of two weeks in the effective operation of the subdrains in spring makes a vast difference in the farming operations of the whole season.

(2) The land along the line of the open drains is often the most productive on the farm and an overflow even for a short time during the summer season would be very destructive. The average rainfall in this district is 32 in. per year with a maximum recorded monthly fall of 8.35 in., yet during the two years the new drains have been in operation the water level has never yet reached the top of the channel, except for short periods at the outlet, and this was caused by backwater from the river. Even in these places the deep channel caused the water to recede in one-fourth the time required before the improvement.

The excavation for the 12- to 16-ft. bottoms was made with a floating dredge having a 1½-yd. dipper and the smaller bottoms were excavated by means of ditching machines, or as they are locally called, "dry-land dredges," with ½-yd. dippers. The contract prices ranged from 6 ct. per cu. yd. for wet dredge work to 10, 14 and 15 ct. per cu. yd. for dry-land work. The assessment sheets including all supervision ranged from $1.25 per acre for wet dredge work to $3.00 per acre for dry dredge work. Notwithstanding the difference in price the dry dredge work is the more satisfactory and wherever a machine of this type is practicable, the taxpayers insist on its use.

Combating Weeds Along Irrigation Canals. W. M. Wayman, in *Engineering News*, July 4, 1912, discusses methods of combating weeds and burrowing animals along irrigation canals. He advocates the use of Ziemsen's weed cutting saw for destroying moss or water weeds. This saw is made of about the thickness of

the ordinary hand saw, is about 3/8 in. wide and has hook teeth on each side. The saw is twisted so that it is turned clear around about once every foot. There are torpedo-shaped weights on this about every 4 ft. which hold it to the bottom of the canal. This saw is operated by a man on each bank and two ordinary men can cut from a mile to a mile and a half of moss in a day. It is usually necessary to place a screen across the canal in some convenient place below and have two men there to pull out all the moss which has been loosened up and floats down to the screen. This saw is handled by Asonert Bros., West Bend, Wis., and a 10-yd. saw complete costs $20. The saw alone is $1.50 per yard.

Dragging a heavy chain along the bottom with a horse on each bank will accomplish the same result.

Luxurious crops of land weeds grow along the banks of canals to such an extent that it is impossible to work on them without first clearing this growth away. As they dry up in the fall and the frost strikes them they loosen up at the ground and the wind blows them into the canal. Frequently ditch banks are lined with weeds of this character. One windy night will put so many in a canal that it will become blocked and often cause serious breaks. They will lodge at every structure and are an item that requires very careful watchfulness and sometimes great expense to avoid serious disaster. In some localities the ditch banks have been cleaned, loosened up and sowed to rye. This rye will reseed itself and in some places has protected the ditch considerably from drifting sands and weeds and wherever rye thrives it will choke the weeds out; aside from this advantage the rye presents a much more pleasing appearance than weeds.

Pasturing sheep is another method of keeping down weeds that has been employed with some success.

It would seem advisable to include the seeding down of canal banks in the original construction contract. This can be done cheapest while the dirt is still soft and clean. Suitable grass seed could be planted with the rye to make pasture for sheep, or to make a permanent sod for bank protection. In dry regions where canals are endangered by blowing sand, such grass could be kept alive by irrigation, watering it by means of a small floating pumping plant and hose.

Cleaning Drainage Ditches with a Water Jet. *Engineering and Contracting*, Oct. 28, 1914, gives the following methods employed in cleaning drainage ditches, as described by Seth Dean, in the Proceedings of the Iowa State Drainage Association:

In the spring of 1910 a bed of silt ranging from 6 in. to 3 ft. in thickness and three-fourths of a mile in length was cleaned from a channel originally cut 16 ft. wide on the bottom. At the time

in question the stream of water flowing over the silt was about 10 ft. wide and 1 ft. deep, the rate of fall being about 2 ft. per mile. There was considerable sand and some drift in the silt but no growth of weeds or brush. The plant used consisted of a scow, 7 x 18 ft. in size and 16 in. deep, made of 1-in. plank. In the bottom of the scow a platform of 2-in. plank was laid to support the machinery, which consisted of a 4-hp. gasoline engine belted to a Myers pump with 3-in. suction and 2½-in. discharge. The pump was equipped with 10 ft. of 3-in. suction hose with strainer on the inlet end, and for discharge had about 15 ft. of 2½-in. fire hose with 1-in. nozzle. The scow when loaded required about 6 in. depth of water to float. Commencing at the lower end of the silt bed the boat was poled forward or held in place, as required, and a jet of water turned through the nozzle into the silt that readily broke and stirred it up, permitting the water to float it away. The work was done in March and April, when the flowing water was clear and capable of carrying silt in suspension; the distance from the center of the silt bed to the outlet of the ditch was about 10.000 ft., and the current sufficiently strong so that little settling of silt occurred. Three highway and one railroad bridge spanned the ditch in the distance cleaned, but the boat readily passed under them. Two men operated the machine and the total amount of silt removed was 2,346 cu. yd. in 33 working days. The cost of the equipment was as follows, viz.:

Scow	$ 45.00
Engine and pump	200.00
15-ft. condemned hose and nozzle	3.00
Belting and fixings	8.60
Freight hauling and setting up	32.00
Two men 33 days at $4	132.00
Gasoline and oil	26.40
Repairs on machinery	1.05
Total	$448.05

After the work was completed the plant was dismantled and the engine and pump shipped to other work which was charged with their cost, thus making the net cost of the plant $248.05 and the cost of cleaning 10.53 ct. per cu. yd.

On one occasion a bed of silt interspersed with logs, brush, cornstalks, etc., was removed, using drags made from the beams and shovels of wornout corn cultivators by bolting the parts together in such manner that they presented the appearance of two anchors placed at right angles. The point of the beam was fitted with a swivel so the implement could revolve. By attaching ropes to the drag, placing a team on each bank and dragging the plow in the channel, the mass was broken up. After pulling out the logs and wire (dynamite being used some-

times to dislodge them) the water floated out the silt. A close measurement of the silt and drift removed from the channel was not made, as the work was done under the day labor system, but approximately 2,800 cu. yd. were taken out, the cost being the following items:

Four team drivers, at $3.50 each for 24 days	$336.00
Two drags with ropes and fixtures	10.00
Dynamite	5.00
Foreman, 24 days at $2.50	60.00
Total at 15 ct. per cu. yd.	$411.00

In the fall of 1912, Seaton's ditch, near Missouri Valley, was cleaned and deepened. This is a drainage ditch 7,600 ft. long with 6 ft. bottom width, and side slopes 1 to 1. During the rainy season and for a time afterward the ditch carries water but is usually dry during the fall months. The work of cleaning was done by contract at 19 ct. per cu. yd. The contractor bid to do the work with teams, but the ground proved too soft for this method, and a small drag line dredge was purchased and the work successfully carried out with this, which proved to be an excellent machine for the work. The machine was made of light timber construction. The framework, 16 ft. wide, was mounted on rollers and designed to work astride the ditch in clean-out work. The power was generated by an 8-hp. gasoline, which also served to move the machine forward or transport it from one job to another along the country roads if the distance is not great. It used a one-third yard scoop. Two men operated it, using about 10 gal. of gasoline per day. About 250 cu. yd. of earth in ten hours was the capacity of the machine on the job in question. The machine is of wood construction and is not very durable, but as most of it is of sizes kept in all lumber yards, defective parts can be easily replaced.

Navigable Canals. These are usually dug through fairly level ground. Their even depth, the continuous use of the same cross-section for great distances, and the large amount of excavation, lead to the use of highly specialized excavating machinery.

The Panama Canal. This was dug under such special circumstances and conditions as to make it unwise to include data on its construction in this chapter. Approximately a quarter of a billion cubic yards of earth and rock were excavated. Reports of the Isthmian Canal Commission, containing considerable cost data, are available to any one who wants to study the subject. A further reason for excluding data on the Panama Canal from this chapter is that it crosses such rough country that the use of special canal excavating equipment was impossible.

The Chicago Drainage Canal. This was dug during 1894 and 1895, largely with steam shovels.

Fig. 29 shows the arrangement of the steam shovels and inclines as operated by one of the Chicago Canal contractors. The traveling incline is provided with a tipple very similar to those used in coal mining. The shovel first takes out a cut 8 ft. deep the full length of the excavation, as shown in Fig. 29 marked 1st cut. The next cut is carried to a depth of 15 ft. and the third cut to a depth of 20 ft. below the original ground level. After the third cut is made, the excavation is carried no deeper until

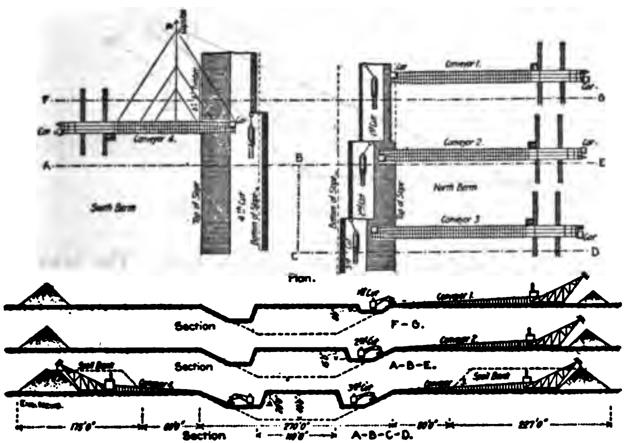

Fig. 29. Arrangement of Steam Shovels and Inclines.

by successive slices the full width of the channel has been excavated. The top lift of 20 ft. being removed, work is begun at the edge of the slopes of the bottom lift exactly as before. In the plan, Fig. 29, the incline or conveyor 4 shows ropes for pulling the approach trestle of the incline forward; a horse whim or block and tackle to the engine being used. The engine and incline proper are carried on a car, the machinery being merely a 10 x 16-in. double cylinder hoisting engine of 75 hp. Actual experience on the Chicago Canal has proved that such an incline can handle 900 cu. yd. per 10-hr. day, day in and day out, the steam shovel being in fact the limiting factor. The trussing of the incline proper and the working of the tipple are shown in Fig. 30, in which M is a sheave around which the cable from the

engine passes to the sheave E, thence to the car; G and H are counterweights that pull the tipple back after the load is dumped. The engineman at no time sees the car, but slows up when he hears the bell rung by the car whose wheel flange strikes a bell lever near the tipple. The front wheels of the car strike a buffer L; the car stops and as the engine is still pulling on the cable, the tipple revolves, dumping the load out of the front end of the car. As the tipple revolves it pulls a wire that operates an indicator in the engine room, so that the engineer knows when to re-

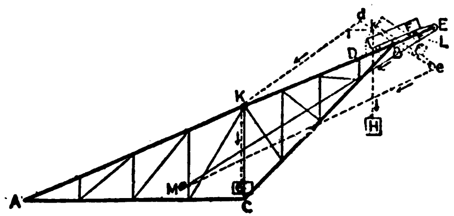

Fig. 30. Incline and Tipple.

lease the cable and let the tipple revolve back. The brake for controlling the descent of the car is operated by a brakeman standing on the incline where he can always see the car. Since there are two cars and two cables there are two brakemen on each incline, each man having a lever connected by wires with the brakes on the engine drum. One of these inclines complete with engines is said to have cost $4,000, and the cost of operation of a steam shovel and an incline per 10-hr. shift was as follows:

4 tons of coal @ $2	$ 8.00
Repairs	8.00
22 men @ $1.50 to $3	44.00
Total	$60.00

Operating continuously from September, 1894, to July, 1895, on the Chicago Canal in hard clay the average output per shift on two sections was 670 cu. yd., making the cost about 9 ct. per cu. yd., not including interest and depreciation of plant. The cost of coal, labor and repairs is about equally divided between the steam shovel and the incline. One contracting firm, with 2¼-yd. shovels, made cuts 20 ft. wide x 20 ft. deep, and moved each shovel forward about 13 times in 10 hr.. making a 6-ft. move each time. It took 2 min. to move the shovel forward, and the incline with the approach trestle rigidly fastened to it was moved at the same time. Each car held 5 cu. yd. place measure, and

was filled with three shovel loads. A ¾-in. wire cable was used in hoisting and its life was 150,000 cu. yd. of material excavated, the cars being moved 350 ft. horizontally and 60 ft. vertically.

Another method of attack using a shovel and incline is shown in Fig. 31. In this case the shovel makes cuts across the axis of the canal instead of parallel with it. It will be noticed that in this case a bridge was used to dump through instead of a tipple, but this same method of shovel attack has also been used with

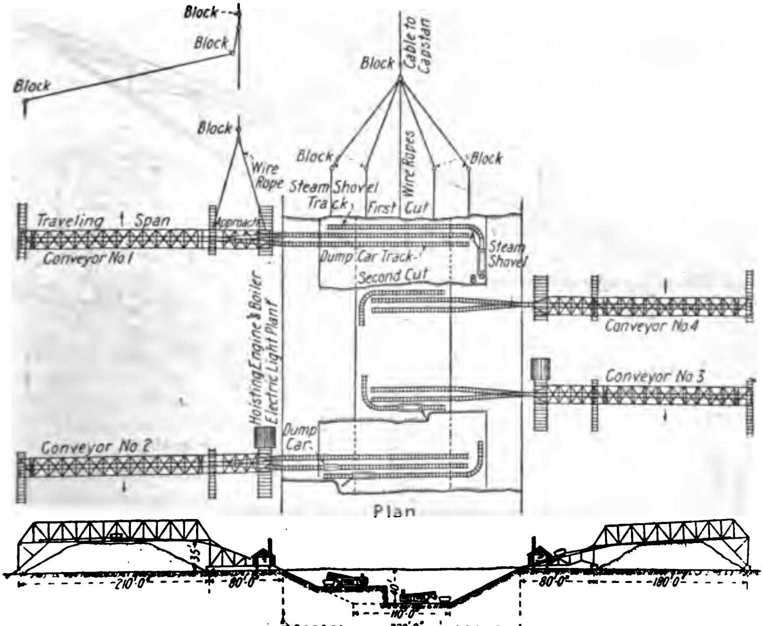

Fig. 31. Shovels Used with Incline and Dumping Bridge.

the tipple incline just described. Using a 1½ cu. yd. shovel, cuts 15 to 20 ft. wide x 16 ft. deep were made, the shovel working for 1 hr. and then moving forward 14 ft. When a cut has been made clear across the canal, the shovel is run around the curved track, as shown at AB, while the working track is shifted close up to the face of the work. At the same time the bridge and incline are shifted by horses a distance of 20 or 25 ft., the whole time so occupied being about 50 min. The cars used with

this bridge conveyor hold 9 cu. yd. water measure, which in blasted hardpan is taken to be equivalent to 5½ cu. yd. place measure. The car has an A-shaped bottom and swinging side doors that are readily tripped, and its dead weight is 10,000 lb. The bridge is a single track combination wood and iron Pratt truss, traveling on tracks as shown. The shovel is the limiting factor, but a maximum output of 210 car loads in 10 hr. has

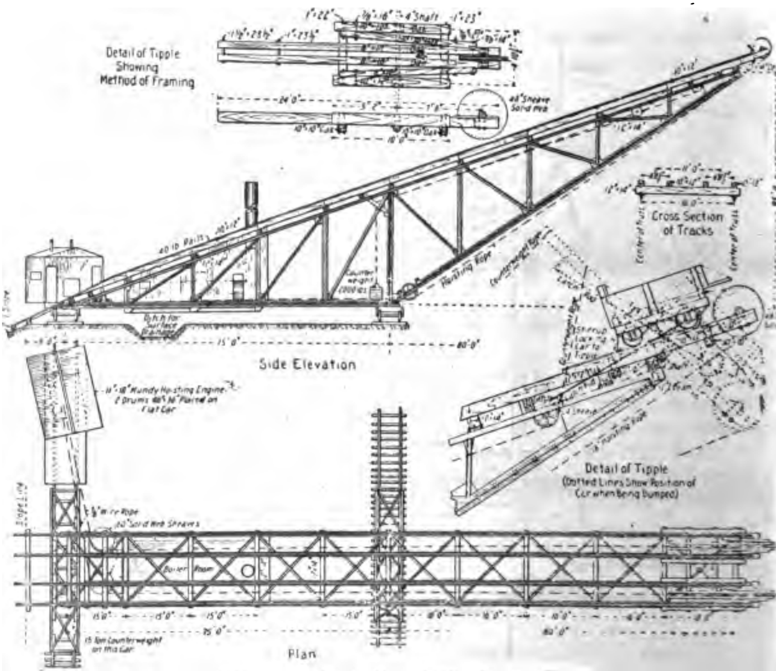

Fig. 32. Details of Tipple Incline.

been attained, although 150 car loads was the average. The force engaged on the Chicago Canal in tough clay was 1 shovel engineman, 1 cranesman, 1 fireman, 5 shovel tenders, 12 laborers breaking down face and trimming slopes, 2 men on bridge truss, 1 engineman and 1 fireman on incline, a total of 24 men besides a foreman. Two centrifugal pumps, one 8-in. and one 10-in. lifting 3,000 gallons per min. 50 ft. high, were used to keep the pit drained, and in this connection it should be observed that pump-

ing cost 1 to 1.5 ct. per cu. yd. Work was suspended during February, March and April, and in the month of January the shovel output was 20 to 30% below the average of other months.

Fig. 32 shows an all steel incline and tipple used on one section instead of the bridge conveyor, but with the same method of shovel attack at right angles to the canal axis, shown in Fig. 31. It will be observed that there was no approach trestle used in connection with this incline, and that the engine house was on a separate flat car. The steel trusses of the incline weighed 5,800 lb., and the total load of boilers, flat cars, etc., was 100 tons. The engines were 11 x 18-in. double Mundy, and with the boiler cost $2,700. The shovel cut was 20 ft. wide x 18 ft. deep and the best month's record was 920 cu. yd. per 10 hr. shift, which was the best record made on the canal for a month.

The Bates Belt Conveyor, Chicago Canal. On section G of the Chicago Sanitary District Canal, a belt conveyor designed by Lindon W. Bates, was installed. The original machine was built with two belts, one horizontal belt across the canal and up the slope, and a second belt up and across a movable bridge. The weight of the load held the belt down at the bottom of the slope. These belts were 22 in. wide, the pit belt being 450 ft., and the spoil bank belt 500 ft. long. The belt traveled on rollers across the valley and up over a movable bridge, off which the earth was scraped by 6-ft. scrapers. The slope of the bank belt was 2.5 to 1. The material was clay, excavated by a steam shovel. As the clay was delivered by the shovel in large lumps, it was necessary to break the lumps up in a "granulator" similar to that used by brick manufacturers. Rain and snow caused slipping and clogging of the belt, and the pit had to be kept dry as the belt would stall when loaded with mud or wet material.

The plant consisted of a 60-hp. Toledo steam shovel, a 120-hp. granulator, and a 50-hp. power car driving the belt. The force employed was as follows:

The belt force consisted of 2 foremen, 1 engineman, 1 fireman, 3 carpenters, 12 pickmen and slopers, 1 dumpman, 1 beltman and 1 oilman.

The granulator force consisted of 1 foreman, 1 engineman, 2 laborers, 1 leverman and 1 hopperman.

The shovel force consisted of 1 shovel engineman, 1 trainman, 1 fireman and 2 pitmen.

The general force consisted of 1 coal passer, and 1 coal cart and driver.

Mr. Schnable, in the *Journal Association of Engineering Societies*, June, 1895, gives the output of this machine as follows:

From May until September was consumed in installing plant,

excavating a pit and in loading the belt by manual labor as well as in experimenting. In October, 77 cu. yd. were excavated per day. In November 920 cu. yd., in December 313 cu. yd., and in January 319 cu. yd. The cold and numerous breakdowns reduced the output for December and January. Mr. Lewis puts the possible maximum output per 10 hr. day of this plant as 1,200 cu. yd. Mr. Schnable's paper gives the general design of this conveyor. This belt conveyor plant was not very successful.

N. Y. State Barge Canal Work. *Engineering and Contracting*, Sept. 28, 1910, gives an outline of the work and costs of handling material with five machines on Contract 42 of the New York Barge Canal. The work was done in April, 1909, on lock 20 and 8.96 miles of canal.

The material handled consists largely of black gumbo (clay), there being little or no rock on the entire contract. Work was commenced in the summer of 1909 at the western end of the contract. At this point three New Era graders, 36 wagons and slip scrapers, and 68 head of mules were employed. The erection of the larger machines was soon put under way and by spring of 1910 all the machines, of which costs are herein given, were working. These machines consist of one Heyworth-Newman dragline excavator, two electrically driven Lidgerwood dragline machines, a Field tower operating a drag bucket, and a 12-in. hydraulic dredge. All machines were operated with three shifts of 8 hr. each. The Lidgerwood machines, however, were working at a disadvantage as they were moving to new points during this month, and the amount of excavation shown for them is merely that skimmed off the surface while moving.

The following data show the costs of excavation per cubic yard for the month of April, 1910. These costs include labor, repairs and distribution of field office expenses:

Heyworth-Newman Excavator, 100-ft. Boom; 2½ Yd. Bucket:

1 operator	$ 4.00
1 foreman	2.00
5 laborers	7.50
1 foreman, average $85 per mo.	2.83
1 pumpman	1.50
1 oiler	2.00
1 team 1 shift a day	4.50
Total cu. yd. for April	23,192
Total cost for April	$1,983.84
Total cost per cu. yd.	$ 0.085

Hydraulic Dredge "Mohawk," 12-in. suction:

1 captain, per month	$ 150.00
3 enginemen, per month	75.00
3 levermen, per month	110.00
1 mate, per month	120.00
6 deckhands, per day	2.00

8 firemen, per day	$ 2.00
8 laborers or pipemen, per day	1.60
Total cu. yd. excavated	15,557
Total cost	$1,726.30
Cost per cu. yd.	$0.111

Two Lidgerwood Excavators, Electrically Operated, with 25-hp. Motor for Swinging and 125-hp. Motor for Hoist; 2½-Yd. Page Bucket:

1 operator, per day	$ 4.00
1 oiler, per day	2.00
5 laborers, per day	1.50
1 sloper, per day	2.25
1 foreman, $85 per mo.	2.83
1 electrician, $125 per mo.	4.17
Total cu. yd. excavated Mach. No. 1	2,271
Total cost	$1,667.80
Cost per cu. yd.	$ 0.735
Total cu. yd. excavated by Machine No. 2	2,583
Total cost	$ 992.30
Cost per cu. yd.	$ 0.384

The two Lidgerwood machines worked only part of the time during this month, No. 1 working 13 days and No. 2 working 10 days during the month. As mentioned above both were engaged in moving to new positions and were working at a disadvantage. The yardage for these machines should be about the same as for a Heyworth-Newman machine under similar conditions. The difference in daily pay roll is, however, in favor of the electrically driven machine.

The electric power on these machines costs about 1 ct. per cu. yd. City current is used and a transformer is placed at convenient points along the line, as the machine moves ahead.

The repairs on the Heyworth machine have averaged, approximately, $400 per month. The highest amount charged to repairs for any one month is $667.

The Field Tower Scraper is a new machine for this class of work and is one of the evolutions of the work on the Barge Canal. It consists of a movable tower, located on one side of the canal with a cable running from it to an anchorage on the opposite side of the canal. The drag bucket is supported by and slides up and down this cable. It is pulled back and forth by an endless line. The crew and costs are as follows per day:

1 operator	$ 4.00
1 fireman, $75 per mo.	2.50
1 foreman or superintendent, $200 per mo.	6.67
1 pumpman	1.50
6 laborers at	1.50
Total cu. yd. excavated	15,065
Total cost	$1,455.81
Cost per cu. yd.	$ 0.096

This tower is 85 ft. high and operates a 1⅞-cu.-yd. bucket with a 10 x 12-in. hoisting engine and 40-hp. boiler. This ma-

chine is becoming quite popular along the canal because of its adaptability and its moderate cost.

Bridge Conveyor Excavator. This machine, used on contract No. 6 of the New York State Barge Canal, is described in *Engineering and Contracting*, Nov. 23, 1910. This excavator was erected in 1907 by the Pittsburg Steel Construction Co. Completely equipped it cost $105,000. The conveyor, Fig. 33, consists of a two-truss "bridge" supported by two steel towers and having a cantilever arm extending beyond the towers over the spoil banks on each side. The bottom chords of the "bridge" carry the truck on which the bucket trolley moves. The towers are 90 ft. high and each rests on a "car" consisting of a framework of

Fig. 33. Bridge Conveyor Excavator on New York State Barge Canal.

steel girders riding on 32 car wheels. The wheel base of these cars is 36 ft., and the cars run on structural gage tracks, one on each side of the canal. One tower, that adjacent to the shorter cantilever arm, is rigidly attached to the car frame. The opposite tower rests on its car frame on two sets of roller bearings. One set of roller bearings permits the tower to move across the car in the line of the axis of the "bridge"; the other set permits the tower to swing on an arc lengthwise of the car or at right angle to the axis of the bridge. The first set of roller bearings permits a certain variation in distance between the cars, and the second set permits one end of the bridge to be "swung" ahead of the other when occasion demands. The total amount of this swing is an arc of 17°.

The cantilever arms differ in length, that adjacent to the fixed tower being 96 ft. span and the opposite one being 128 ft. span. The reason for this design was that the original plans called for the earth to be wasted on one bank and the rock on the opposite bank. The ratio between the lengths of the cantilevers is the ratio between the widths of spoil banks as figured on the engineers' estimates of the amounts of earth and of rock excavation. The longer arm was to provide for the larger rock spoil bank. It may be noted here that this original plan for the separation of the earth and the rock spoil has not proved to be completely practicable and has been only partially accomplished.

The operating mechanism consists first of the mechanism for operating and controlling the excavating bucket, and second of the mechanism for moving the conveyor along the work. All this mechanism is operated by electric power. A service transmission line along the canal brings current at 4,100 volts a. c. from the plant of the Rochester Railway & Light Co., to a transformer car attached to one of the towers and traveling with the conveyor. At this point the 4,100-volt alternating current is transformed to 260-volt direct current and led to the various operating motors.

One set of feeders passes up the tower to a set of contact rails suspended from the lower chords of the bridge. From these rails it is taken by contact shoes on the trolley and conveyed to a switchboard and controllers in the trolley cab. Another set of feeders runs to four 30-hp. motors which move the conveyor along the work. These motors are geared to drums carrying cables the ends of which are led ahead to deadmen on opposite banks of the canal. To control the travel of the conveyor there is an electric brake on each car; these brakes are applied automatically when the current is shut off from the motors.

The trolley is propelled back and forth along the "bridge" by two 60-hp. motors, and a round trip from the middle of the bridge to either end and return requires about 1½ minutes including the time for dumping the bucket. An air brake is arranged to stop the trolley at any desired point and there is also an electric emergency brake to prevent over-running in case of failure of the air brake. Air for this brake and also for the brakes on the hoist, which are mentioned later, is supplied by a small electrically driven compressor located on the trolley.

The bucket is of the clam-shell type and is operated by two pairs of cables, one for opening and one for closing the jaws. Each pair of cables is wound on a separate drum and each drum is operated by two 80-hp. motors. To lower the bucket the closing cables are run slack and the opening cables sustain the bucket until it touches the ground when the opening cables are

also slacked off to permit the jaws to bury themselves in the spoil. As soon as the bucket is buried, the closing cables are hauled in to close the jaws and then both pairs of cables, opening and closing, are operated to hoist the bucket and its load. The combined power of all four motors, or 320-hp., is thus available for hoisting. The controllers for the bucket operating drums are inter-connected with air brakes so that as soon as power is thrown off the drums are locked fast and the bucket can be lowered only at will.

The bucket weighs 9 tons and has a nominal capacity of 8 cu. yd. The actual load grasped, however, averages more nearly 3 cu. yd. A single operator in the trolley cab controls all movements except that of pulling the conveyor ahead which is directed from a cab in one of the towers by the oiler.

The conveyor requires nominally three men, an operator, an oiler and an electrician. The full crew working is larger, and the total wage charge per 8-hr. day includes the following items:

1 operator	$6.00
1 electrician	4.00
1 oiler	3.25
2 to 5 laborers at $1.50 and $1.60	$3.00 to 8.00
1 team	4.00
1 watchman	2.00
Bookkeeper, part time at	$125 per mo.
Timekeeper, part time at	80 per mo.
Superintendent, part time at	250 per mo.

The records of operation of the conveyor, which have been secured, cover the work of the calendar years 1908 and 1909. During this period the machine was laid up an aggregate of about two months because of repairs due to a fire and to the breaking of the bucket.

The cost of removing earth and rock were not kept separate. In 24 months 510,406 cu. yd. of rock and 39,721 cu. yd. of earth were removed at the following cost per cu. yd.

Repairs	$0.0400
Electric power	0.0484
Drilling	0.0212
Blasting	0.0715
Removal of spoil	0.3091
Total per cu. yd.	$0.4902

This cost does not include interest or depreciation.

It will be noted that practically all the excavation was rock. Since 1 cu. yd. of solid rock makes about 1.7 cu. yd. of broken rock, if we divide the 40 ct. cost of "removal of spoil" and "repairs" and power by 1.7 we get about 24 ct. as the cost of loading and conveying a cubic yard of loose material, which would

be about the cost of handling earth with this bridge conveyor, exclusive of interest and depreciation.

During the 24 months the conveyor handled 510,000 cu. yd. of solid rock (equivalent to about 860,000 cu. yd. of earth) and about 40,000 cu. yd. of earth. Hence it would have handled 900,000 cu. yd. of earth in 24 months, or 37,500 cu. yd. per month.

Costs on the N. Y. Barge Canal. In a paper presented before the Philadelphia Engineers' Club and published in the July Proceedings, 1911, Wm. B. Landreth, former Special Deputy State Engineer in direct charge of the Barge Canal construction, presented data showing the contract prices of barge canal construction covering several years. These prices are for the larger items of contract work and show large variations in prices bid for various classes of work. The first contracts were let in 1905, and bids have been received several times every year since that date. This period covers at least one rather severe financial depression and two periods of increased cost of work.

But one unit price is paid for excavation as there is no classification of the material excavated.

The actual cost to the contractors as shown in the cost data records, including depreciation, interest and overhead charges, has been as follows per cu. yd.:

EARTH EXCAVATION

By hydraulic dredge	from $0.05	to $0.16
By dipper dredge	from 0.13	to 0.30
By ladder dredge	from 0.15	to 0.25
By clamshell dredge	from 0.09	to 0.15
By revolving excavator and scraper bucket	from 0.05	to 0.28
By towers and scraper buckets	from 0.11	to 0.30
By steam shovel	from 0.10	to 0.40
By graders	from 0.14	to 0.30
By hand and team	from 0.14	to 0.60

ROCK EXCAVATION

Dry rock by steam shovel	from $0.30	to $0.75
Dry rock by hand and derrick	$2.00 (average)	
Wet rock	from $1.00	to $2.25

Channeling has cost from 22 ct. to 38 ct. per sq. ft., depending on the character of the rock, the rock channeled having varied from soft, badly broken shale and slate to hard limestone.

Scraper Boat for Sloping Canal Banks. A machine for sloping the banks of the New York State barge canal to any required grade was devised by A. S. Robinson and described in *Engineering Record*, May 23, 1914. It consisted of two scows joined together but separated so as to leave a well between them (Fig. 34). In this well was the base of two triangular cantilever trusses. These trusses supported a track on which a 1-yd. drag-line bucket oper-

Fig. 34. Sloping Boat Devised for New York State Barge Canal Work at Rome, N. Y.

ated. This bucket had a lateral movement of 30 ft. for one setting of the boat. The cutting edge of the bucket scraped the soil downward into the water where a curvature of the track caused the bucket to tip and dump its load. The bottom of the canal was previously excavated by suction dredges to a depth sufficient to receive this material. The back of the bucket had two flap valves

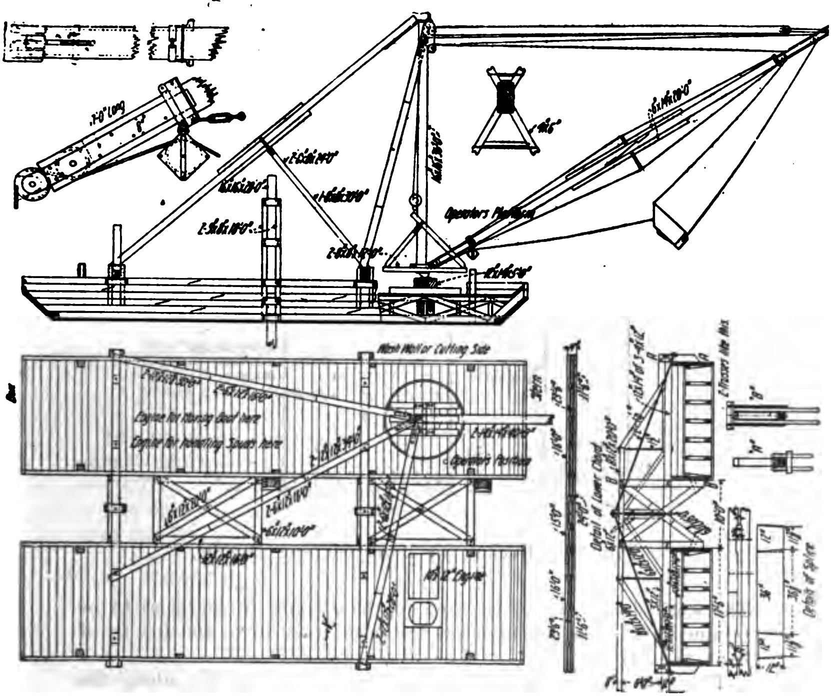

Fig. 35. Details of Bank Sloping Dredge.

opening inward for the purpose of permitting water to enter and wash out the bucket on its return trip.

Another boat for shaping canal banks is described in *Engineering and Contracting*, Nov. 9, 1910. It consists of a derrick set on one of two barges which are each 17½ x 75 ft. and fastened parallel to each other with a 10 ft. space between. (See Fig. 35.) The engine for operating the derrick and bucket is set on the second barge opposite to the location of the derrick. The der-

rick is equipped with Terry & Tench fittings. The dimensions are indicated on the drawing, which shows the method of operating the bucket. The bucket (Fig. 36) digs with an upward motion, being pulled by the line attached to the cutting end. Two lines are fastened to the rear of the bucket, one of which runs over a sheave in the end of the boom and is used to dump the bucket. The other runs directly from the back of the bucket through a sheave at the base of the mast and is used to haul the bucket back.

The lines are operated by an 10 x 12-in., double drum, Lidgerwood engine. Two other engines, each 6 x 10 in., located near the bow, are used respectively to operate the lines connected to deadmen up and down stream, and to operate the spuds. One operator, a fireman and five men constitute the usual crew on this machine.

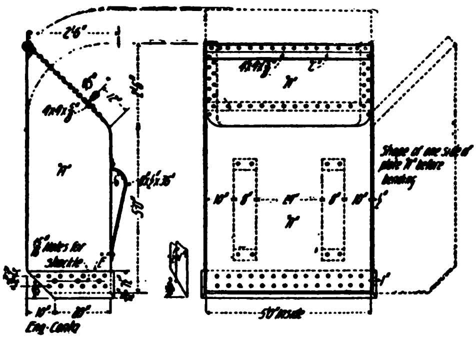

Fig. 36. Bucket for Bank Sloping Dredge.

The work done varies according to the amount of material to be trimmed off. The machine has trimmed from 50 to 400 lin. ft. of bank per day of 8 hr.

Templets are set at various intervals (about 25 ft.) along the banks, indicating the correct slope and the grade to which the operator works. The slope is produced by holding the boom at a certain angle with the horizontal, which once having been found by the "cut and try" method, generally need not be changed while digging the one class of material. This "sloper" was designed by George E. Field.

There were 20,000 ft. B.M. in the derrick, trusses and housing, exclusive of the lumber in the scows.

Cost of Steam Shovel Work, North Shore Channel, Chicago. *Engineering and Contracting*, Aug. 4, 1909, gives the following costs of work on Section 1 of the North Shore Channel of the

Sanitary District, Chicago. This section comprises the pumping station and lock, the crib work piers protecting the intake, the lock and 3,350 ft. of channel. The work was done by the Sanitary District on force account.

The top 10 ft. of channel excavation consisted of a clay which could readily be dumped from dump cars, but below this the clay was heavy and tenacious and came in large lumps. It was excavated by a 70-ton Vulcan steam shovel with a 3-cu. yd. dipper. The steam shovel loaded into Western 3-cu. yd. dump cars which were handled by Davenport locomotives out of the cut and onto the crib piers behind which the spoil was dumped. These cars were dumped in the usual way until the sticky clay was met, then they would not dump properly. A derrick was then arranged to do the dumping. A sling was devised which would hook into and lift the car body from the trucks and by winding up on the engine would tilt the body and empty it.

The cost of excavation, as kept by the engineers, was as follows for 1908, when 194,280 cu. yd. were excavated: An 8-hr. day was worked and the wages paid were as follows:

Men on dump per day	$1.50
Men around shovel per day	1.75
Steam shovel enginemen per month	125 to 150
Steam shovel cranemen per month	90

The value of the excavating plant was $16,035, and the assumed depreciation chargeable to Section 1 was $16,035 × 50% = $8,017.

The cost of excavation (194,280 cu. yd.) in 1908 was as follows per cu. yd.:

	Total	Per Cu. Yd.
Materials:		
Operation	$ 8,639	$0.044
Repairs and plant	7,156	0.036
Total materials	$15,795	$0.081
Labor:		
Operation	$32,241	$0.166
Repairs and plant	3,295	0.016
Total labor	$35,536	$0.182
Grand totals	$51,331	$0.264

The items making up these totals were as follows:

Materials:	Operation	Rep. & Plnt.	Total
Shovel	$1,208	$1,502	$ 2,710
Dinkeys	753	1,148	1,901
Track	0	2,222	2,222
Dump	259	0	259

Materials:	Operation	Rep. & Plnt.	Total
Cars	$ 216	$1,863	$ 2,079
Coal	6,066	0	6,066
Office	0	360	360
Insurance	0	0	0
General	136	61	197
Totals	$8,638	$7,156	$15,795
Labor:			
Shovel	$ 8,728	$ 820	$ 9,548
Dinkeys	5,876	359	6,265
Track	5,951	0	5,951
Dump	9,146	0	9,146
Cars	34	1,975	2,009
Coal	585	0	585
Office	0	8	8
Insurance	606	0	606
General	1,315	103	1,418
Totals	$32,241	$3,295	$35,536

The costs of operation in excavation were distributed as follows:

Steam Shovel:	Total
Labor	$ 8,880
Coal	3,326
Supplies	1,208
General	539
Totals	$13,953
Per cu. yd.	0.072
Transportation:	
Labor	$ 6,023
Coal	3,326
Supplies	1,003
General	182
Totals	$10,534
Per cu. yd.	0.054
Track:	
Labor	$ 6,102
General and supplies	190
Totals	$ 6,292
Per cu. yd.	0.032
Dump:	
Labor	$ 9,298
Supplies	259
General	539
Totals	$10,094
Per cu. yd.	0.051
Grand totals	$40,873
Per cu. yd.	0.209

The costs of repair and plant charges were distributed as follows:

Steam Shovel:	**Total**
Labor	$ 280
Materials	1,502
General	177
Totals	$2,499
Per cu. yd.	0.006
Transportation:	
Labor	$2,364
Material	3,011
General	177
Totals	$5,552
Per cu. yd.	0.014
Track:	
Materials	$2,222
General	177
Totals	$2,399
Grand totals	$10,460
Per cu. yd.	0.027

In figuring the net costs of repairs and plant charges the total estimated amount of excavation on the section, or 390,000 cu. yd., has been used as the divisor. The reason for this is that the repair and plant charges itemized were all that were necessary to put the plant in shape to complete the work. Summarizing we have:

Operation	$0.2095
Repair and plant charges	0.0266
Depreciation on plant	0.0205
Total per cu. yd.	$0.2566

Cost with Dragline Excavators on North Shore Channel, Chicago. Sections 4 and 5 of the North Shore Channel, Chicago, were dug under contract. The top-soil on both these sections was excavated with teams and drag scrapers. In this way 47,000 cu. yd. were removed from section 4, and 21,000 cu. yd. from section 5. The balance of the cut was made with Heyworth-Newman dragline excavators, one machine working on each section. *Engineering and Contracting*, Apr. 27, 1910, gives the following data on their operation. On section 4, from Sept., 1908, to Dec., 1909, inclusive, 499,062 cu. yd. were removed, or an average of 31,191 cu. yd. per month. On section 5 201,712 cu. yd. were moved from May to Dec., 1908, inclusive, an average of 25,214 cu. yd. per month.

An estimate of the cost of labor for one machine is as follows: No consideration is taken of interest on contractors' bond, insurance, or of general office expense. The work is divided into three shifts of 8 hr. each for the operators, and two shifts of 12

hr. each for the balance of the crew. The work is carried on 6 days a week or 25 days a month. The figures were obtained by the editor while going over the work and are given according to the information furnished him. He believes, however, that the crew given for each machine is too large. It would be more nearly correct to eliminate the items of mechanic, blacksmith's helper and oiler; and to divide the blacksmith's time between three machines. The monthly payroll was:

12 laborers at 20 ct. per hr.	$ 720.00
3 operators at $150	450.00
2 firemen at $90	180.00
1 man and team	125.00
1 supt. to 2 machines at $200 per month	100.00
1 civil engineer and timekeeper, $125 — 2 machines.	67.50
1 mechanic, 3 machines at $150	50.00
1 blacksmith	90.00
1 blacksmith's helper	50.00
1 oiler	60.00
Total per month	$1,892.50

Using 31,191 cu. yd. excavated for Section 4 and 25,214 cu. yd. excavated for Section 5, the costs per cubic yard are estimated as follows:

Section 4

Labor	$0.061
3 tons coal per 24-hr. day	0.010
Repairs and miscellaneous supplies	0.048
15% annual interest on $15,000 plant	0.006
50% annual depreciation on $15,000 plant	0.020
Total per cu. yd.	$0.145

Section 5

Labor	$0.076
3 tons coal per day	0.012
Repairs and miscellaneous supplies	0.059
15% annual interest on $15,000 plant	0.007
50% annual depreciation on $15,000 plant	0.030
Total per cu. yd.	$0.184

The labor item includes all work done, such as repairs, moving machine, and actual excavation.

The "repair and miscellaneous supplies" item is large. It contains new cable, oil, renewals and 2 miles of 2-in. pipe to supply water to the boilers. The strains and work demanded of large dragline machines are heavier than steam shovels. The average repair and maintenance bill has been $1,500 per month for two excavators.

The annual interest and depreciation charges are estimated high in order to make allowance for periods of idleness when no contract is underway.

Tower Dragline Excavator on North Shore Canal, Chicago. A machine invented by J. T. Fanning, which is said to have worked very close to required lines, cutting less than 1½ cu. yd. of excess material per lin. ft. of canal, is described in *Engineering and Contracting*, Jan. 18, 1911.

Fig. 37 shows the principles upon which the machine operates. There are two towers and two buckets. In each tower is located a double drum engine which operates one of the buckets. The booms, which extend on an incline to the rear of the tower and over the spoil bank, are also offset horizontally from the center lines of the towers. This can better be understood by reference

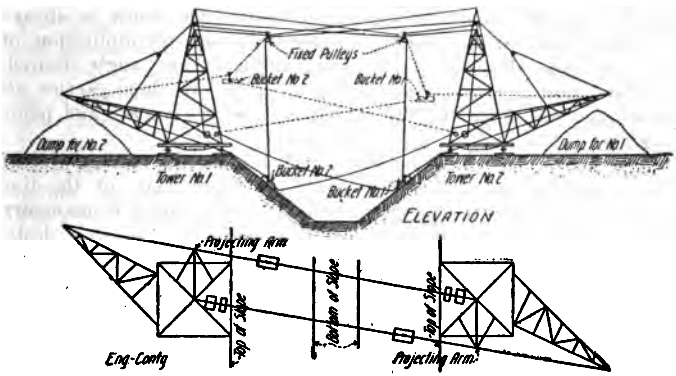

Fig. 37. Method of Operation of Double Bucket Tower Excavator.

to the plan. The boom on one tower is offset to one side of the center line which runs between the two towers, and the boom on the other tower is offset to the opposite side of this center line. In this way a straight line from the apex of one tower to the end of the boom of the opposite tower, shows a clear working line for the bucket. A similar condition is presented for another bucket to work in the opposite direction.

Each bucket is operated by two lines. The drag or digging line is run from the small drum of the double drum engine to the bucket which digs downwardly on the opposite bank of the canal. The bucket is dragged down the slope, with its other line slack, and takes its load. The other line of load line runs from the large drum on the engine up over a pulley near the apex of the tower, then out over another stationary pulley which is suspended from a cable placed between the two towers, down through

a sheave attached to the bale of the bucket, and out to the end of the boom on the opposite tower. By winding in on this line and holding the dragline, the bucket is raised until, by slacking the dragline, it can be run down by gravity to the dump pile at the end of the boom. The location of the bucket in digging was controlled partly by the location of the fixed pulleys suspended above the canal section. The positions of these were changed from time to time to suit the requirements of the work.

The bucket is of ¾-yd. capacity, and is arranged so that a tripping device, near the end of the boom causes the bottom of the bucket to swing loose and drop the load on the spoil bank.

In operation the skill with which the bucket is handled depends upon the experience of the engineer. The work is always in plain view of the operator, and by proper manipulation of the lines the slopes may be carved down at any angle desired. The constant rubbing of the buckets down the slope carries all loose material down the bank, and produces a compact and plane surface.

The bucket travels very easily and rapidly out to the end of the boom, the speed being controlled by the angle of the line on which it runs and by the dragline. Some speed is necessary to enable the bucket to throw out its load. The speed is desirable because the clay sticks to the bucket.

The principal disadvantage comes in the wear of the dragline which bears a considerable strain when used to stop the bucket.

The material excavated is clay. The section of the canal measures 26 ft. wide at the base with slopes of 1 on 2. The average depth of the canal on the sections which this machine was used, is about 27½ ft. The country through which the canal runs is a practically level plain.

The machine was used on two sections of the North Shore Drainage canal, covering a period of two years. It was operated 10 hr. per day with an engineer and fireman in each tower, and a track gang consisting of about 5 men. An average of 12 men, including the superintendent, watchmen and all labor, was employed. The maximum yardage excavated, during one month, was in June, 1910, when 19,000 cu. yd. were excavated. The minimum yardage for a complete month was excavated in December, 1908, when 4,750 yd. were taken out. The average amount of excavation per working day was between 500 and 600 cu. yd. It was possible for each bucket to make two trips per minute, but the output per day shows that each bucket averaged less than one trip per minute.

The new machine, for which plans are being made, will be built stronger throughout, and a larger bucket will be used.

Costs of Excavation on Colbert Shoals Canal, Ala. Charles E. Bright, in *Engineering and Contracting*, Oct. 18, 1911, gives the following:

Colbert Shoals Canal, which was designed to overcome the obstructions to navigation at Colbert and Bee Tree Shoals, is located along the south, or left bank, of the Tennessee River; the lower end of the canal being about one-half mile above Riverton, Ala. It is a lateral canal 8 miles long, with a lock of 26-ft. lift, 80-ft. width, and 350-ft. length, located at the lower end. Beginning at the upper end of this lock and extending upstream for a distance of 5.3 miles, the canal was excavated through the bottom lands, the cutting ranging in depth from 17 ft. at the lower end to 20 ft. at the upper.

The cross section of the canal is 112 ft. wide at the bottom or at grade, with side slopes of 1 on 2. Berms 15 ft. wide between slop stakes and the toe of spoil banks were left on both sides of the canal, the berm on the river side being brought to a height of not less than 9.5 ft. above low water in the canal.

Excavation was done on different sections of the canal with wheel-scrapers, elevating graders pulled with traction engines, dragline excavators and steam shovels.

The elevating graders were not generally successful. Grass and cornstalks clogged the elevator on one part of the work so that it was necessary to strip the surface with wheel scrapers.

All of the graders used were what is termed "Standard Western Elevating Graders," with 21-ft. elevator, using an extra heavy or giant railroad plow for loosening the material and throwing it on the elevator. This plow was attached to one side of the frame of grader. The only portion of the canal completely excavated to grade by these machines was from Stations 10-20 to 145-163, which proved unprofitable on account of the material usually becoming too hard near the bottom to be loosened by the plow. The height to which the material had to be lifted in getting it to spoil banks was too great. These machines, in connection with wheel scrapers, were most successfully used in making a cut from 8 to 12 ft. in depth, and 110 to 120 ft. in width, off the top. This left a strip about 30 ft. wide inside the slope stakes on each side for the drag bucket excavators to work from in taking out the remainder of the section. This arrangement gave the elevating graders the soft material to which they were best adapted, and, at the same time, the least lift in conveying the material to spoil banks.

The steam shovel outfit consisted of a 65-ton Marion shovel, one 25-ton and one 20-ton dinkey locomotive, and eight "Oliver" 12-yd., side dump cars, all standard gage; with about 1¾ miles

of track, a tank, and pipe line and pump for supplying water to shovel and locomotives.

The dragline excavators were Armstrong machines equipped with an 81-ft. boom and a 2-cu. yd. Page scraper-bucket. The machine was moved on skids with wooden rollers.

Quantities Handled and Cost by Various Methods

	Per. Cu. Yd.
Wheelscrapers, 207,408 cu. yd.	$0.20
Graders, 917,138 cu. yd.	0.17
Dragline, 889,267 cu. yd.	0.11
Steam shovel, 187,559 cu. yd.	0.28

The wheel-scrapers, elevating graders and steam shovel having removed the cream of the excavation in most instances, the drag-bucket excavators were left the hard material which was mostly found near the bottom, besides being required to lift the material to a greater height. An advantage of the drag-bucket excavators over the wheel-scrapers, elevating graders and steam shovel, was their ability to work successfully in pits containing from 2 to 3 ft. of water, and the fact that ordinary rains did not interfere with their output. It was also the only machine on which two and three shifts per day were worked profitably.

The daily expenses by each method were as follows:

Drag-Bucket Excavators:	
3 enginemen at $260 per month	$ 8.66
3 firemen at $2	6.00
3 laborers at $1.50	4.50
1 master mechanic at $125 per month	4.16
1 pump man	1.50
1 blacksmith	3.00
1 foreman at $75 per month	2.50
1 coal wagon driver	2.00
Total per day	$32.32
Cost for each of 3 machines	10.77
Elevating Graders:	
2 enginemen at $80 ($160)	$ 5.33
2 firemen at $1.75	3.50
16 teams (four-horse) at $2.50	40.00
1 water wagon, with driver	2.00
1 pump man	1.50
1 blacksmith	3.00
1 helper	1.50
1 foreman at $75 per month	2.50
Total per day	$59.33
Cost for each of two graders	29.66
Wheel Scrapers:	
15 wheel scrapers at $2	$30.00
3 snap teams at $2.25	6.75
5 laborers at $1.75	8.75
1 blacksmith	3.00
1 helper	1.50
1 foreman at $75 per month	2.50
Total per day	$52.50
Cost for each scraper	3.50

Steam Shovel:

1 foreman at $125 per month	$ 4.16
1 shovel engineman at $125 per month	4.16
1 craneman at $90 per month	3.00
1 shovel fireman	2.00
1 blacksmith	3.00
1 helper	1.50
1 pump man	1.50
1 coal wagon	2.00
2 dinkey engineers at $2.00	4.00
2 firemen at $1.50	3.00
2 brakemen at $1.50	3.00
16 laborers on dump at $1.50	24.00
3 laborers at shovel	4.50
Total per day	$59.82

Bibliography. "Hand Book of Construction Plant," R. T. Dana; "Excavating Machinery," A. B. McDaniel; "Practical Farm Drainage," C. G. Elliot; "Irrigation Engineering," Herbert M. Wilson; "Irrigation Engineers' Hand Book," Herbert M. Wilson.

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CHAPTER XVIII

HYDRAULIC EXCAVATION AND SLUICING

To California gold miners and mining engineers the world is indebted for the development of the cheapest means known for moving earth. Engineers in general are apparently strangers to the great economy of the hydraulic method of excavation, or if not ignorant of its economic merits as applied in California, they hesitate to use the method elsewhere. However, there is nothing mysterious or difficult about the hydraulic method of earth excavation, nor does it always require so great an expenditure for plant as to put it beyond the reach of those contemplating excavations of any considerable size. It is generally assumed that there must be a gravity supply of water, but even this condition is no essential to economic excavation and transportation of earth, as we shall presently see.

There are three methods employed in sluicing: (1) the ground-sluice; (2) the "boom," and (3) the hydraulic giant.

In the ground-sluice method, which is best adapted to shallow banks, the earth is shoveled or dumped into a stream of water running in a sluice. In this method the water is used to convey the material and not to loosen it.

A "boom" consists of a temporary dam behind which the water supply is allowed to accumulate until a sufficient amount is stored. The water is then allowed to escape with a rush, the stream being directed against the foot of the bank to be removed. This method has been used in Colorado.

Hydaulic Giants. A giant or monitor is a metal tube and nozzle tip so fixed to a pipe by flexible joints as to be easily moved horizontally or vertically. The tapering nozzle varies in diameter from 1 to 10 in., at the tip, and is fitted with a deflector attached at its extremity for the purpose of directing the stream to the desired point of attack. See Fig. 1.

Bed Rock Sluices. In opening up a gold-bearing gravel bank for hydraulic sluicing bed rock sluices are frequently constructed. These are channels cut in the underlying bed rock for the purpose of conveying the material to the outlet pipe or sluice or to the dump.

The grade of the bed rock sluice is determined by the contour of the ground, the quantity of water available, and the character of the material. Sand requires a heavy grade which may be partially compensated by making the sluice wide and shallow. Heavy boulders require a deep narrow sluice. The usual grade is 6 in. per "box" of 12 ft. in length, or 4.2%, but will vary from 1 in. to 12 in. per "box." The grade should increase slightly towards the dump. Curves should be avoided if possible. It is

sometimes necessary to set the sluices in tunnels but open cut sluices are preferable.

The size of the sluice is also regulated by the quantity of water used, according to H. A. Brigham, *Journal of the Associated Engineering Societies*, vol. 41, 1908. For washing fine material the size of sluice required is about as follows:

Quantity of water Miner's in. (1.5 cu. ft. per sec.)	Width of sluice ft.
200 to 600	3
400 to 1,200	4
1,000 to 2,500	5
2,000 to 4,000	6
3,000 to 5,000	8
4,000 to 7,000	10

Fig. 1. "Bouery's" Hydraulic Giant.

The most economic method of constructing bed rock sluices is to blast the material, wash out the débris with the hydraulic giant, and line the sluice if necessary with timber.

The Carrying Capacity of Water. To the engineer, the most important data relating to hydraulic excavation are results of actual practice showing the number of cubic yards of material excavated by a cubic foot of water. The most complete information on this subject is given in a paper on "Hydraulic Mining in California," read by Mr. A. J. Bowie, Jr., in 1877, before the American Institute of Mining Engineers. From this paper, which goes into great detail, I have condensed and tabulated the accompanying Table II, which is based upon actual measurements and is reliable.

The total yardage was 2,275,967 cu. yd. gravel moved per 1,533,728 miner's inches (2,159 cu. ft. each), or 1.48 cu. yd. moved per miner's inch, which is equivalent to about 1,440 cu. ft.

of water per cu. yd. of gravel; 12,027 oz. of gold worth $231,893 were recovered, the average yield per cu. yd. of gravel being 10.2 ct.; 554 lb. of quick-silver were lost. The average cost per cu. yd. of gravel moved was:

Water	$0.008
Materials	.010
Labor	0.036
Office and general expenses	.006
Total per cu. yd.	$0.060

Two shifts were worked and 1,520 (24-hr.) days were required to move the two and a-quarter million cubic yards, or about 1,500 cu. yd. per 24-hr. day per plant.

TABLE I—COST OF HYDRAULIC EXCAVATION: NORTH BLOOMFIELD—CLAIM NO. 8

Year	1874–5	1875–6
Cu. yd. gravel	1,858,000	2,919,700
Height of bank, ft.	180	260
Grade of sluices, in. in 16 ft.	6½	6½
Labor per cu. yd.	$0.0122	$0.0140
Powder per cu. yd.	.0032	.0053
Materials per cu. yd.	.0030	.0031
General expenses per cu. yd.	.0022	.0025
Water per cu. yd.	.0077	.0074
Total per cu. yd.	$0.0203	$0.0323
Cu. yd. of gravel per miner's inch	4.80	4.17
Cu. ft. water per cu. yd. gravel	450	520

The foregoing indicates about the maximum cost of hydraulic excavation on a large scale, for the banks were not very high, the head of water was low, and the flumes were laid on a very gentle grade—all of which factors increase the consumption of water, as is well shown by comparison with Table II.

Contrast Table II with the following data, Table III, on the North Bloomfield Mine which is rearranged from a table given by Mr. Bowie. Here the grade of the sluices is 9% instead of 2%.

TABLE III—DATA ON NORTH BLOOMFIELD MINE

	1874	1875	1876	1877
Height of bank, ft.	100	100	200	265
Grade of sluices, in. in 12 ft.	6½	6½	6½	6½
Cu. yd of gravel	3,250,000	1,858,000	2,919,700	2,993,930
Cu. yd. per miner's inch	4.6	4.8	4.17	3.86
Cu. ft. water per cu. yd.	436	459	540	567

Sluices on the North Bloomfield Mine were 6 ft. wide by 32 in. deep, while those used for the La Grange Mines were 4 ft. wide by 30 in. deep.

We see from Tables I to III that the cubic feet of water

TABLE II — COST OF MINING FIVE CLAIMS OF THE LA GRANGE HYDRAULIC MINING COMPANY
(1874–6, Inclusive)

	Claims				
	French Hill	Light	Chesnan	Johnson	Sicard
Height of bank, ft.	10 to 40	24 to 60	12 to 62	20 to 40	20 to 40
Head of water, ft.	50 to 70	60	50 to 80	80	90
Nozzles, size, in.	4 to 6	6 and 7	6 and 7	....	....
Grade of sluices, in. in 16 ft.	4 in.	4 in.	3 to 4 in.	3½ in.	3½ in.
Total cu. yd. of gravel	679,968	683,244	284,932	196,632	155,347
Cu. yd. gravel per miner's inch (2,159 cu. ft.)	1.08	1.82	1.87	1.76	2.89
Cu. ft. of water per cu. yd.	2,000	1,186	1,577	1,227	757
Labor per cu. yd. gravel	$0.0420	$0.0220	$0.0360	$0.0200	$0.0250
Blocks and lumber per cu. yd. gravel	.0042	.0080	.0042	.0029	.0061
Materials per cu. yd. gravel	.0057	.0015	.0062	.0076	.0038
Water per cu. yd. gravel	.1040	.0060	.0080	.0060	.0040
Refining gold per cu. yd. gravel	.0004	.0003	.0005	.0004	.0007
Total per cu. yd. gravel	$0.1563	$0.038	$0.055	$0.037	$0.039

required to move each cubic yard of gravel may be from 450 to 2,000; and that the cost of labor alone may be 1.25 to 4.25 ct. per cu. yd. It appears that ordinarily about 1,000 cu. ft. of water are required to loosen and move each cubic yard of gravel where banks are, say, 30 ft. high, with about 85-ft. head of water.

As illustrating the expense to which certain companies have gone, the 55 miles of main ditch of the North Bloomfield Co. may be mentioned. This ditch was 5 ft. wide at bottom, 3.5 ft. deep, and side slopes were 1.5 to 1. The grade was 12 to 16 ft. per mile, and the delivery 3,200 miner's inches, or about 6,900,000 cu. ft. per 24 hr. Ditches with grades of 20 ft. per mile and delivering 80 cu. ft. per second have been built, and it is to be noted that gagings show about 25% less discharge than open-channel formulas would indicate. Where ravines are crossed, timber flumes 4 ft. wide by 3 ft. deep laid on grades of 30 to 35 ft. per mile are used.

The sluices into which the loose gravel and water are run are made of 1.5-in. plank, tongued and grooved about 3 ft. wide x 3 ft. deep; cross-sills, 4 x 6 in., support the sluice every 4 ft., being mounted on 4 x 6-in. posts. The sluices ordinarily have a 4% grade, and one of the size just given will carry 3,200 miner's inches on a 4% grade; 6 to 8% grades are used where pipe-clay is to be moved. The water must run at least to 10 or 12 in. deep in the sluice, so as to cover boulders of that size and facilitate their moving along. A sudden break or drop-off in the sluice line can be used to effect the disintegration of cemented gravels.

Banks of cemented gravel, often weighing 3,600 lb. per cu. yd., or 133 lb. per cu. ft. in place, are broken up by using black powder. If the bank is 50 to 125 ft. high a tunnel is run in about two-thirds the height of the bank, and at the end of the tunnel lateral drifts are run parallel to the face, forming a T. One-half to ⅔ keg (25-lb.) of powder per 1,000 cu. ft. of gravel, measured in front and above the lateral drift, is the charge placed in the lateral drifts, tamped and fired. As illustrating the accuracy of sampling the yield of gravel determined by test pits and drifts, one example will suffice. Excavations from which 21,600 tons of gravel were taken actually yielded $2.75 per ton in gold, while the estimated yield by sampling was $2.00.

For data on bank blasting see Chapter V.

Many data on the "duty" of water are given by A. J. Bowie in "A Practical Treatise on Hydraulic Mining." Amounts varying from 1 to 7.5 cu. yd. are given as transported by a miner's inch in 24 hr. This is roughly from 1 to 10% as many cu. ft. of material moved as there are cu. ft. of water used to move it. On Yuba River, Calif., some 19,100,000 cu. yd. of gravel were

moved with 3.5 miner's inches per cu. yd. On American River, Calif., 8,615,000 cu. yd. required 4.5 miner's inch per cu. yd.

Volume of Water for Hydraulicking. Table V was compiled by engineers of the Union Iron Works Co., San Francisco, Cal., published in their catalog No. 5, on hydraulic excavating machinery, and given in *Engineering and Contracting*, June 12, 1912.

TABLE V—WATER REQUIRED FOR EFFECTIVE HYDRAULICKING, CU. FT. PER MIN.

Head ft.	2-in. nozzle	2½-in. nozzle	3-in. nozzle	4-in. nozzle	5-in. nozzle
100	120	188	278	488	750
150	150	233	338	600	938
200	158	270	390	690	1,073
250	195	300	435	773	1,200
300	210	330	480	848	1,320
350	225	360	508	915	1,425
400	240	383	548	975	1,500

The catalog gives a table for nozzles up to 10 in. and heads up to 700 ft. The volume of water increases as the square of the diameter of the nozzle.

The Miner's Inch. *Engineering and Mining Journal*, May 26, 1904, gives the following:

In the *California Journal of Technology*, A. P. Stover gives the number of miner's inches assumed in different states to equal a flow of 1 cu. ft. per second.

	By custom	By statute
California	50.0	40.0
Colorado	38.4	38.4
Montana	40.0	40.0
Idaho	50.0	....
Arizona	40.0	....
Nevada	50.0	....
Utah	50.0	....

In Nevada the miner's inch in one part of the state may be measured under 4-in. pressure, while in another part under 6 or 12-in. pressure. Along the Humboldt River water, in some cases, is measured under pressures of 2, 3.5, or even 4 ft. The great difficulty is to obtain a constant head; this may be done with flows of small volume by use of a proper measuring box, but it is impossible with flows of several hundred feet per second.

Ditches and Flumes. Where lumber is cheap and where the required life of the water supply line is not much more than 10 yr., the cost of a flume is frequently less than that of a ditch. A larger amount of water per unit of section area is carried by flumes than by ditches. Waste gates should be placed every ¼ to ½ mile.

Giants have been designed to accelerate the movement of ma-

terial through flumes, ditches and ground sluices. See Fig. 2, which shows a "booster giant" made by the Joshua Hendy Iron Works, San Francisco.

A Giant and Hydraulic Elevator Plant. *Engineering News*, Jan. 16, 1896, gives the following:

In an exhaustive paper on "The Present Condition of Gold Mining in the Southern Appalachian States," by Messrs. H. B. C. Nitze and H. A. J. Wilkens, presented at the Atlanta meeting of the American Institute of Mining Engineers, the authors describe a novel method which is about to be used in reworking the

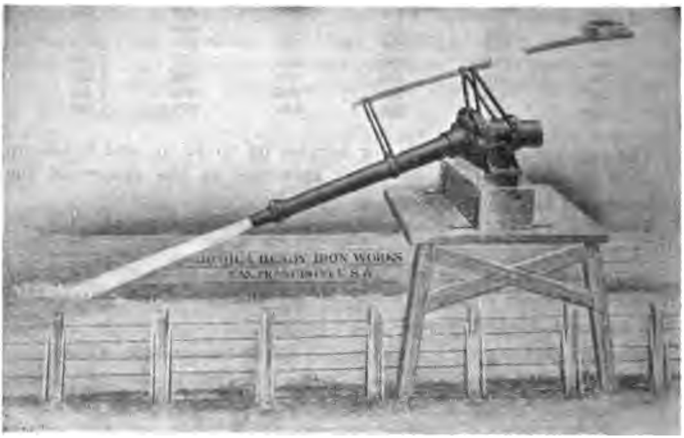


Fig. 2. A Booster Giant.

old placer-deposits on the Mills property, Burke Co., N. C. The work is described as follows.

The deposits are situated near the headwaters of Silver Creek. They are about a mile in length and are located mainly upon the west bank upon which the gravel often extends out a distance of 500 to 600 yd. The main difficulty encountered is the want of fall in the bed, a feature common to many Southern placers. It amounts in this case to less than 1 ft. in 100. To overcome this obstacle for hydraulicking with continuous sluice, the use of the hydraulic gravel-elevator was decided upon, and some experiments were made with it a few years ago. In the main, they were satisfactory, but were soon abandoned, the plant being unfit for continuous use, and monazite not being at that time a valuable product.

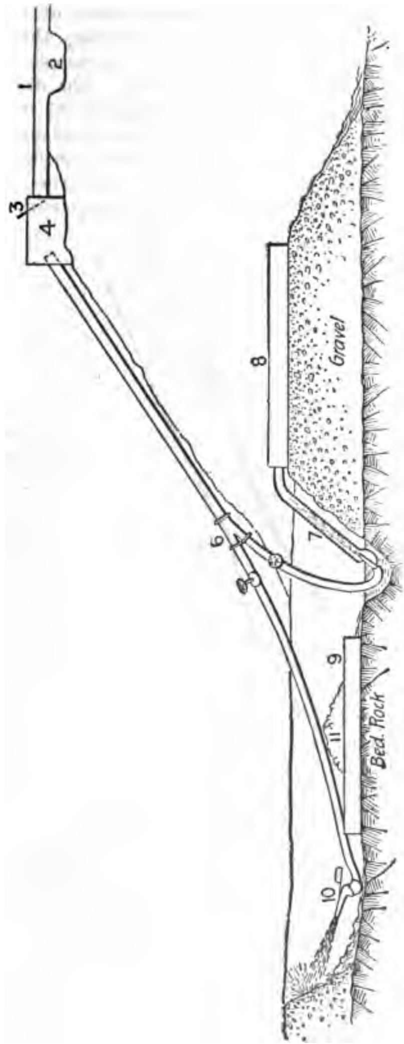


Fig. 3. Giant and Hydraulic Elevator Plant. 1, ditch; 2, sand-pit with drain; 3, screen at head of penstock; 4, penstock; 5, pipe (10 and 8-in.); 6, Y branching into two 7-in pipes; 7, elevator; 8, top sluice boxes; 9, pit sluice boxes; 10, giant; 11, boulder and pebble heaps.

Fig. 3 gives a rough sketch of the plant and method to be carried out by the present company. Twelve miles of ditch and flume line (1) carry the water from a reservoir, through the Dan Sisk gap in the South mountains, to a penstock (4), situated 200 ft. above the level of the creek bed. The ditch is cut about 8 in. deep by 20 in. wide, at a cost of about 25 ct. per rod, and is given a grade of from 1½ to 3 in. wide by 12 in. deep.

The water, before reaching the penstock, flows through a sand-pit (2, Fig. 3), to catch sand, etc., washed into the ditch line from the side. It then enters the penstock after passing through

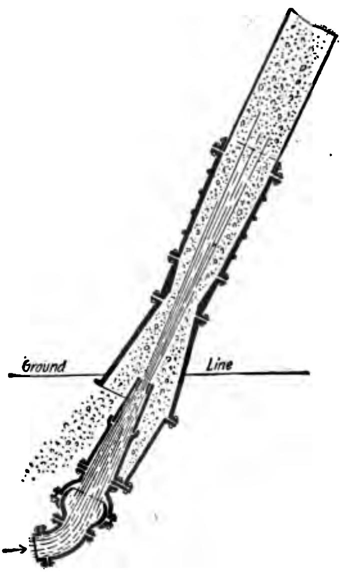


Fig. 4. Hydraulic Gravel Elevator.

a screen (3) for removing leaves, sticks, etc. The pipe (5) running from the penstock is 10-in. spiral riveted sheet-steel (No. 16 Birmingham gage), coated with coal tar and connected with flanges. Smaller curves are made by placing cast-iron beveled wings between the gaskets of the flanges, larger ones by suitable elbows. Near the gravel pit the 10-in. pipe branches out through a Y (6) into two 7-in. pipes, supplied each with a gate-valve, one leading to the giant (10) and the other to the hydraulic elevator (7). These are both of California type and manufacture.

An illustration of the elevator is given in Fig. 4. The principle of this device is too well-known to require a description. It is intended to keep the elevator stationary as long as possible, as its installation consumes considerable time. A pit must be sunk in the bed-rock, and as the elevator must also drain the workings (a drain on the top of the bed-rock to the initial point of working was considered too expensive), the water would gain too much headway while the elevator is moved. The work in the main pit will be carried diagonally up the banks of the stream, so as to gain as much grade as possible. As soon as there is room, a sluice box (9) will be placed between the working-bank and the elevator pit.

The upper part of this sluice will be filled with 3-in. by 4-in. blocks and the remainder by 1-in. by 3-in. cross-riffles, placed 11 in. apart and held down by a sand-board, which is halved down on them. Both will help to protect the sluice box against wear. All pebbles, etc., more than ½ in. in diameter will be forked out of the sluice and left in the pit (11). After being raised by the elevator, the material will pass through another sluice (8), the tailings from which will be worked for monazite. It is expected that by far the largest part of the gold will be saved in the first sluice.

An Incline and Giant. In Siskiyou County, Cal., according to *Engineering and Mining Journal*, Nov. 16, 1912, an incline and a giant are used instead of a hydraulic elevator. The incline is an inclined trough, usually 8 ft. wide and 80 to 100 ft. long. The sides range from 12 ft. wide at bottom to 6 ft. at top. The bottom is composed of two sets of 1¼-in. plank. A bridge, usually 10 ft. long, of well supported boards, extends from the gravel to the incline. This bridge and the first 20 ft. of the incline are lined with ⅜-in. steel plates. In operation two or more giants are employed: the first cuts down the deposit and the second, located about 80 ft. from the bridge, washes the material up and over the sloping bridge by the driving power of the water. As much as 1,200 cu. yd. of gravel per day have been handled by two No. 3 giants using 1,200 miner's inches of water under 450-ft. head. Boulders as large as 5 ft. in diameter are driven over the incline. In some of the placers this method is used in pits 20 to 25 ft. deep.

The machine is unhandy to move. Four men with a capstan, block and tackle and a mule will change the location of a machine in 8 or 9 days.

The cost of operation is stated to be 6 or 7 ct. per cu. yd.

Hydraulic Elevator Work in Alaska. The following is given by C. W. Purington in *Mining and Scientific Press*, Apr. 26, 1913.

Unfrozen gravel is handled on claims of the Pioneer Mining Co. on Anvil Creek, Nome, Alaska, with a hydraulic giant, assisted by a bedrock sluice, a hydraulic elevator and a nozzle for washing away the tailings. The gravel is coarse and sub-angular, with many medium sized boulders. Eighteen men and 1 team are employed on each 10-hr. shift. About one-half the men are employed cleaning bed rock, and the team of horses is used for removing stones larger than 8-in. in diameter, that will not go through the elevator throat.

The duty of the miner's inch — considering all operations — is 2.63 cu. yd., or 30.4 cu. yd. of water are required to move 1 cu. yd. of gravel. The total amount of water used during an operation of 29 days in September and October, 1911, was 15,733 miner's inches which moved 41,415 cu. yd. Of this water only 20.4% was used for the piping giant, while 4.2% was used for the bedrock sluice, 8.3% for the tailings giant, and 67.1% for the hydraulic elevator. If all the water available was used for piping giants, then the duty of the miner's inch would have been about 12.38 cu. yd. for an average daily yardage of 6,716 cu. yd.

The elevator was of the Campbell type, having a 10.5-in. throat and upcast pipe 15 in. in diameter. The bed rock sluice was of steel, and the face was carried as much as 150 to 250 ft. from the throat of the elevator. This machine raised the gravel 26.5 ft.

Transporting Sand Through a Pipe with the Aid of an Ejector. *Engineering and Contracting*, July 7, 1909, gives the following:

For transporting sand from a scow to a tank, a distance of 630 ft., an ejector was used. A line of 4-in. cast iron pipe ran from the ejector to the tank. The total lift from the scow to the tank was 30 ft. The sand was shoveled into a hopper attached to the ejector. The diameter of the nozzle of ejector was 1½ in., and the diameter of the water jet was 1 in. The water pressure at the jet was 110 lb. per sq. in. There were 80 cu. yd. of sand transported per 10-hr. day by this method. Incidentally the sand was well washed, for the overflow water from the tank carried off the silt.

Removing Muck from a Bridge Caisson by a Hydraulic Elevator. *Engineering and Contracting*, July 12, 1911, gives the following relative to work on the sub-structure of a bridge at Vancouver.

The hydraulic elevator is operated on the same principle as a steam syphon or ejector, water being used at about 100 lb. pressure to lift the material out of the pit. The elevator (Fig. 5) consists of a V-tube through which the water is forced. The "down" pipe is 4 in. in diameter and the "up" pipe 5 in. Near the lower end of the up pipe is a Y-branch leading to the

material to be excavated. The material is agitated by means of a jet pipe which also is shown in the drawing.

The former method used for taking out the soft muck first encountered in the caisson was to blow it out through a pipe by means of the air pressure in the caisson. This could only be done intermittently because of blowing off all the air. By the hydraulic elevator the operation is continuous and the air pressure within the caisson may be maintained. No trouble has been experienced by the air escaping, as one might suppose. When the elevator is not actually excavating, a board is placed under the

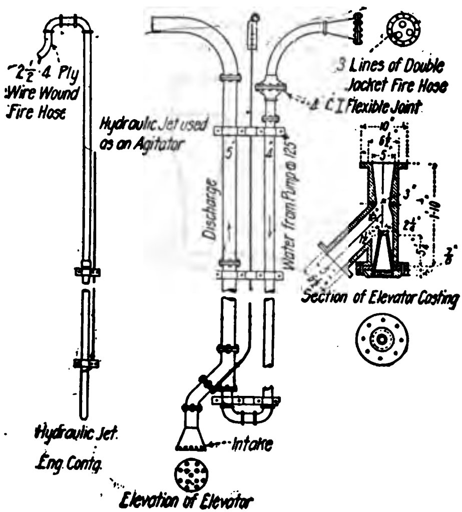


Fig. 5. Hydraulic Elevator and Jet Used for Excavating and Discharging Material from Caissons of Vancouver Bridge.

suction and the water from the pump is simply allowed to flow through the pipes. The pump used is a duplex pump furnishing water at 100 lb. pressure at the pump.

By a comparison of the two methods in caissons of equal size — 16 ft. square — it was found that with the use of air pressure 123 cu. yd. were blown out in 42 hr., whereas 115 cu. yd. were taken out in 19½ hr. with the hydraulic elevator. This is 2.93 and 5.90 cu. yd. per hr. respectively, or an increase of 100% by the use of the hydraulic elevator.

Pressure Boxes. A pressure box is located at the intake of

the pipe line leading to the giants. It should be spacious and the water should stand 4 ft. or more deep over the entrance to the pipe to prevent the entrance of air. Provision must be made for the overflow when the gates in the pipe line are closed.

Pipe Lines for Hydraulic Mining. *Engineering and Contracting,* Dec. 11, 1907, gives the following:

In hydraulic mining in Alaska the water is distributed from the pressure box to the monitors and elevators by means of wrought-iron or more generally, steel-riveted pipe, usually made up in sections 17 to 19 ft. long. Sheet steel is used, from 8 to 16 U. S. standard gage, bent, each plate, 30 or 36 in. long, being riveted in double rows lengthwise and single on the ends. The sizes used vary from 8 to 36 in.

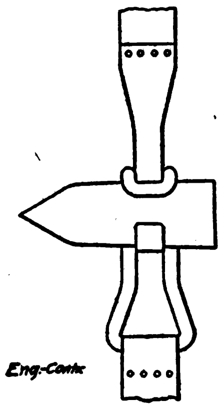


Fig. 6. Reinforcing a Slip Joint.

The pipe is shipped by the manufacturers, either made up and riveted ready to be laid with slip joints, or the material is supplied in short plate sections, bent, punched and furnished with necessary rivets, ready to be cold riveted on the ground.

Sections of pipe are put together by slipping or by flange or lead joints. If it is advisable to reinforce a slip joint, the device shown in Fig. 6 which can be made quickly in a blacksmith shop, is often used. The sleeve, lugs and keys should be made of soft steel.

In laying pipe from the pressure box to the placer claim, the line should be started at the lower end, and the joints slipped in down the slope. In cold climates the best practice is to lay the pipe line in a slight lateral curve, so that subsequent contrac-

tions of the units may be remedied by pushing the pipe into a more nearly straight line. The pipe should be laid as nearly straight as conditions will allow, and elbows and bends of small radius should be avoided.

Various methods of "setting" the pipe are used. In Oregon the device shown in Fig. 7 is used in setting and unsetting pipe.

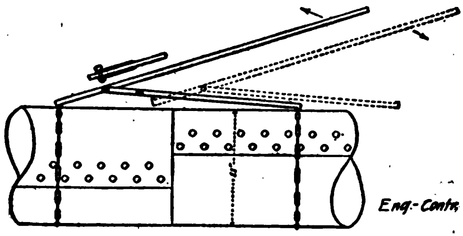


Fig. 7. Oregon Method of Jointing Pipe.

The wrench is made with reversible parts, so that the position of the leverage can be changed for the different operations. Another device sometimes used in British Columbia is shown in Fig. 8. It consists of a square block of timber 3 ft. x 3 ft. x 9 in.,

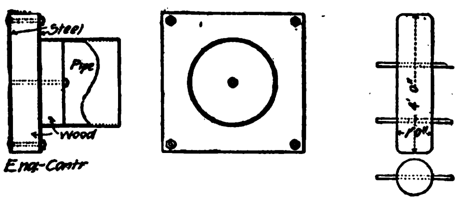


Fig. 8. British Columbia Method of Jointing Pipe.

faced with 1/16-in. steel plate, to which is bolted a disk-like wooden plug the diameter of the pipe inside. Two men batter the timber with mallets.

Lead joints are seldom necessary in Alaskan operations, the almost universal practice being to use slip joints.

On steep declivities pipe joints are braced and strengthened by means of lugs and wiring as shown in Fig. 9.

Ditch Construction in Alaska. Chester W. Purrington, in a U. S. Geological Survey *Bulletin*, abstracted in *Engineering and Contracting*, Jan. 1, 1918, says that ditches on the Seward Peninsula are made with breaking plows, scrapers and road graders,

all being drawn by horses. Four or eight horses are used on a grader, two to four on a scraper. Special methods are necessary when the ditch passes through sections underlain by ground ice, or runs over sections of rock that are broken and fractured. It has been found bad practice to cut through the stringy moss which overlies the masses of ground ice, generally referred to as "glacier." In fact it is disastrous to the permanency of that section of the ditch, and is the beginning of never-ending repairs, since the ice continues to thaw, causing constant leakage. The best practice is to build sod walls on the lower side, leaving the moss

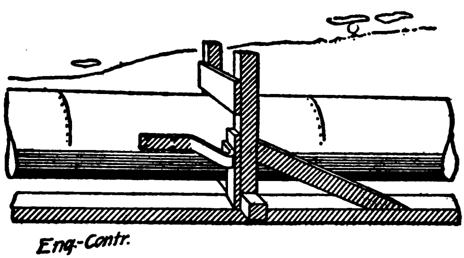


Fig. 9. Bracing Pipe on Slopes.

undisturbed. All rock work must be done by hand, and where the ditch passes through fractured material all cracks must be filled with moss. Too much care can not be observed in the latter detail, and, especially during the first weeks of use, men must be kept constantly traversing and repairing those sections where leaks are apt to occur. The stirring up of the water by men walking along the bottom of the ditch is a good practice in the early stages, for silt, in addition to the sod, is a most valuable factor in filling the cracks.

A scraper will work to great advantage in decayed schist, which needs no lining, as it holds water better than any other ground encountered and cuts out less. Fluming does not pay when there is a possibility of ditch building. In fact, it has been often stated by men familiar with ditch construction, that where possible, it is profitable both as regards first cost and subsequent maintenance to build a ditch in place of fluming, even if the distance necessary to be covered by the former be ten times that of the latter.

Many slopes apparently not permitting a ditch cut, owing to the presence of broken rock and talus slides, on close examination are found to be favorable, for if 2 or 3 ft. of this loose material is moved there are excellent opportunities for comparatively cheap

rock cuts. When, however, it is deemed impracticable to construct a ditch, and where a flume must be built crossing a gully, a very efficient foundation can be made by digging shallow holes, filling with gravel, and placing on top a wide plank to distribute the load. If the trestle rests on such foundations, and the underlying ice is not disturbed, much trouble from settling will be avoided.

The following are a few of the costs representative of ditching in various materials:

	Per cu. yd.
Soft muck and tundra	$0.75
Gravelly dirt	0.65
Decayed schist ..... $0.40 to	0.60
Rock work, fairly solid	1.75
Schist in place	1.00
Loose rock	1.25

A ditch carrying 1,000 miner's inches will cost, under fair conditions, $2,000 per mile. One with the capacity of 4,000 miner's inches will cost between $4,000 and $5,000 per mile. Though much affected by varying local conditions a conservative estimate for general work is $1 per cubic yard throughout.

A Simple Timber Flume. Two flumes, over 800 ft. long and 2½ x 2 ft., and one 400 ft. long and 5 x 4 ft., were required to be built for the Santa Rita Mining Co., in Colombia, South America, and only native carpenters with peon helpers were available. All framing had, therefore, to be designed so that measuring and thinking would be unnecessary by the carpenters. The design selected to meet the conditions and the method of constructing the flume are described in *Engineering and Mining Journal* by R. D. O. Johnson and abstracted in *Engineering and Contracting*, Apr. 17, 1912.

The boards were all 1½ in. thick and 12½ ft. long, making the flume boxes average 12 ft. in length. Since it cost as much to edge and to handle a 6-in. board as it did a 12-in. board, the use of narrower boards was not frequently allowed.

All boards were sawed by hand, the sawyers working in pairs. The sawyers were at first put at day's pay, but it soon became evident that the lumber would cost $40 per M. It always pays to put the peon on contract where possible. As the peon knows nothing of the measurement of lumber by the board-foot unit and as it appeared a hopeless task to explain it to him another method had to be devised. The work of the best pair of sawyers was taken as a guide and a schedule of prices was worked out for each size of board or timber needed. These prices were calculated on a cost of $18 per M, the prices being a small amount higher for the thin and narrow boards and a small amount less

for the large boards and timbers. This scale of. prices was accompanied by simple specifications as to the kind of timber acceptable, full dimensions, bark edges, worm holes, rotten spots, etc.

Contracts were given to each pair of sawyers for a limited number of boards and timbers on the basis of the specifications and price schedule. Each sawyer was charged 25 ct. gold per day for his board, the cost to the company being somewhat below this figure. It was found desirable to give small contracts rather than large ones. Boards were inspected each day and a record of the work of each pair of sawyers kept. Failure to keep to the

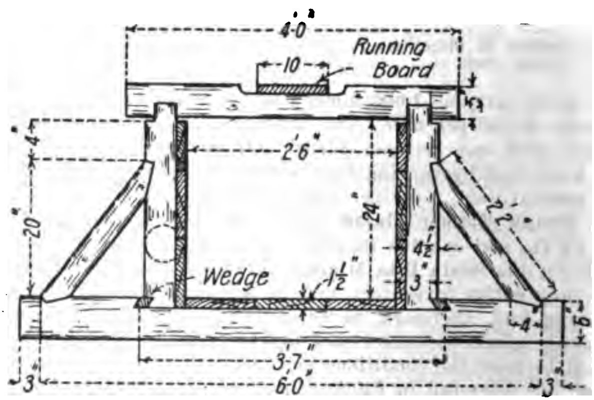


Fig. 10. Cross Section of Timber Flume Built by Colombian Native Labor.

specifications was met with the penalty of severe docking. The prices were found in practice to be about right as, on the contracts, the better sawyers could make about 50% more than the ruling day's pay for sawyers, and the poorer ones were either eliminated or had to be content with less than the ruling rate.

In searching for bunches of good trees, so that the cost in time and labor in handling the logs would be less, the sawyers would sometimes go to great distances from the sites of the flumes, making the cost of collecting boards excessive.

To obviate this difficulty a price of from 1 to 3 ct. a board, depending upon the size, was added to the contract price and the sawyers were required to deliver their boards at the flume site. All boards were brought to dimensions and edged at a price of 5 ct. per board. The boards were not tongued and grooved, reliance

for the tightness of the flumes being placed on careful edging. As the boards were finished they were marked and distributed along the lines of the flumes. As the woods were full of small and fairly straight trees, it was determined to make the frames out of the round timber without even going to the trouble and expense of taking off the bark. The accompanying cross-section of the flume (Fig. 10) shows the frame, the parts of which are of much more ample diameter than the working stresses would ordinarily require, but the timber was plentiful and the large diameters made up for the mark and the weakening due to the cutting out of crooks and bends. Miter boxes were used to cut the sills, caps, posts and braces to reduce the cutting to mere mechanical operations.

The sills, caps and braces were of round timber cut on contract, sills 6 ct., caps 3 ct. and braces 1 ct. each. The cutting of the posts required the combined labor of three carpenters and was not given out on contract. The wedges were made from 1½-in. hardwood boards, 10 in. wide, and sawed into 12-in. lengths. These short sections were inserted in the wedge miter box, wedged tightly, and sawed. Each 12-in. section makes four wedges, two rights and two lefts. For the total number of wedges the labor of one carpenter for six days was required.

As the sills were completed they were laid out upon the shelf excavated to receive the flume, lined up carefully, spaced and given the proper inclination on the curves. When all the boards had been sized and edged and all parts of the frames formed up and distributed along the line of the flume, four native carpenters and four helpers (peons) laid the flume at the rate of 120 ft. per day. The process was as follows:

The ends of the boards of a box were carefully fitted to the end of the preceding box already laid, the lower side boards were then spiked to the outer bottom boards; the bottom as a whole was then carefully adjusted to the centers of the sills, the posts set up and the wedges started. The center bottom board was then spiked to the sills, the lower side boards spiked to the posts, the caps placed and spiked and the wedges driven up hard. The outer bottom boards were then spiked to the sills and the braces driven into their recesses in the sills and posts and spiked. The posts were not spiked to the sills, so that the wedges could be driven up later if it appeared desirable to do so. The necessary sequence of the operations involved in laying the flume was carefully explained to the carpenters and, with a little practice, they acquired the "swing" and the work thereafter moved off at a satisfactory rate. Little calking of the flume was found necessary. Although ½ x 3-in. battens were provided, few were used.

Exclusive of the work of excavating the shelf and on the two trestles on the line, the cost of the smaller of the two flumes was 45 ct. per running foot.

Movable Flume on Hydraulic Fill Dam. The following appeared in *Engineering Record,* Jan. 6, 1917:

During the construction of a large hydraulic fill dam recently

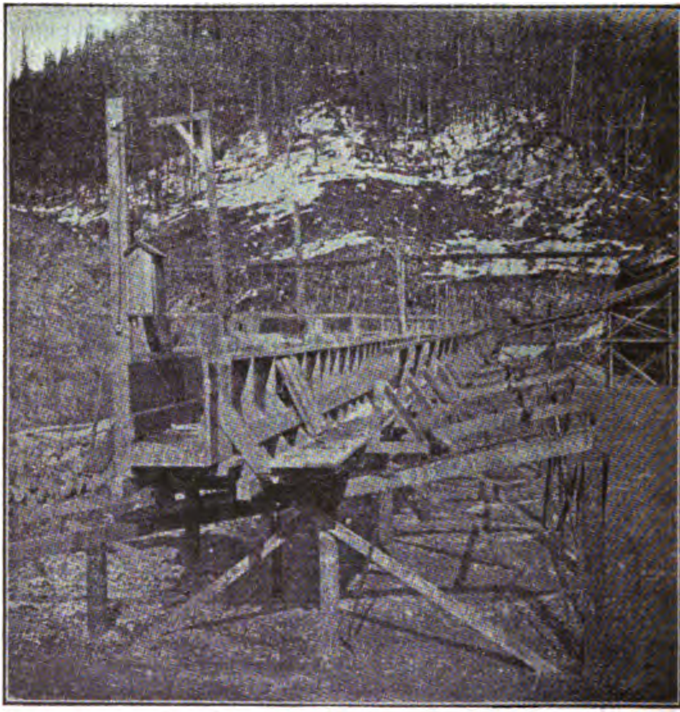


Fig. 11. Discharge Flume Easily Moved on Inclined Skids.

completed in the West, considerable time was saved by the use of an inclined runway for the flume from which material was deposited on the dam. Although the flume was moved by hand, it was only necessary to interrupt the flow for short periods while the delivery flume was skidded up the incline to the desired new position. See Fig. 11.

Three borrow pits were used, from which, by means of hydraulic giants, material was sluiced into three main flume lines. From these mains the material was conveyed through flumes along the upstream and downstream sides of the fill. By the use of gates the streams were discharged from the flumes at the desired intervals toward the axis of the dam.

The flume box, 12 x 24 in. in section, was built up of 1¼-in. boards and was paved with 6 x 12 x 6-in. hemlock blocks set on end. Immediately above the blocks 1 x 6-in. projecting strips were nailed on each side. This box was supported on 2 x 6-in. stringers, which in turn were carried by 4 x 6-in. caps on the low sliding bents spaced 15 ft. apart and inclined on a slope of 5 to 1. The 6 x 6-in. inclined caps were supported on pieces of the same size resting on the material previously deposited and tied together by cross-bracing.

The flume proper was moved up the incline by means of a lever and chain device at each bent. The lever consisted of an iron bar near the lower end of which was fastened a chain connecting with the framing of the flume box. At the extreme lower end of the bar a second chain was attached which passed over an iron claw fastened to the upper end of the inclined 6 x 6-in. cap. This lever was operated by one man at each bent. With the lever in an upright position, pulling it down through the quadrant, which it was possible to describe, would move the flume up the incline a few inches. This gain was then caught by taking up slack in the chain at the claw, and the operation repeated.

Short lengths of lateral flumes were attached to the openings in the up side of the flume box to facilitate control of the flow. Doors for closing the openings were provided, so that material could be discharged at any desired point along the crest of the fill, a duplicate line of flume being used along up and down stream faces. Of course each time the flume was moved, it was necessary to establish a new connection at the point where it was fed from the supply flume.

Sluicing was carried on practically continuously night and day, in order to save time, and the movable feature of the flume was considered to be a factor in the progress of the job.

Sluicing Sand and Gravel in Steel-Lined Flumes. *Engineering Record*, Dec. 20, 1913, gives the following account of hydraulicking at a gravel pit on Puget Sound near Tacoma, Wash., where the conditions of the plant are such, that an ordinary 1-in. board in the flume bottom will wear through in about two days, and the cost of maintaining any of the ordinary forms of flume block paving has proved prohibitive. The unusual severity of the wear is caused by the fact that the flume grades have been kept down

to 8 and 10%, and about 1.6 cu. yd. of sharp material are carried for every 1,800 gal. of water pumped. The advantage of this is that a daily output of 1,800 cu. yd. is maintained with a pumping equipment which is considered comparatively light for the yardage handled.

The deposit lies at the water's edge in a bank rising to an elevation of 240 ft. above mean low water, and all buildings, bunkers and loading dock are supported on piles in deep water. Flumes from the pit discharge into separators which feed a 500-cu. yd. gravel bunker and a 350-cu. yd. sand bunker. The bunkers discharge through twenty under-feed gates into 4-yd. bottom-dump cars which can be hauled to the end of the dock and emptied into scows at the rate of 6 cu. yd. per minute. Water is supplied to the pit from the Sound by two duplex compound steam pumps — one with 10 x 16 and 12 x 18-in. cylinders, the other with 8 x 12 and 10 x 16-in. cylinders. From these pumps a 10-in. riveted steel pipe line runs to the pit, paralleled by an 8-in. auxiliary line. The average lift of the water is 100 ft., and at this head these pumps normally deliver 1,800 gal. per minute. This delivery for 18 or 20 hr. per day is sufficient to bring to the bunkers the full capacity of 1,800 cu. yd.

Three separators are in use, fed by three 130-ft., 12 x 12-in. flumes which branch from a main flume 24 in. wide and 12 in. deep. This main flume, which runs to the face of the pit, has a length of 100 ft. and is fed by numerous branch flumes of equal depth and 15 in. in width. From these branches 12 x 12-in. laterals are laid to attack the bank at any desired point. All these flumes in the pit are on an 8% grade, the three separator lines having a 10% grade.

With the low velocity of water and the very heavy percentage of suspended matter the wear on the bottom of these flumes was so great that at first no material could be found which would fulfil the requirements of hardness and cheapness with a low coefficient of friction. Finally the expedient of buying old band-saws from the lumber mills was adopted, and the use of these saws to take the wear met with success, from the start.

The flumes are built of 1 x 12-in. rough lumber, chiefly in 6-ft. sections, and this construction lends itself readily to the use of band-saws, which come in 10, 12 and 14-in. widths. In the 12 x 12-in. flumes a single saw blade is laid in the bottom and a three-cornered wooden strip nailed over it at the corners to hold it in place. In the 24-in. flume circular saw blades, sheared to the proper widths, were used in the same way.

The band-saws are usually 12-gage, while the circular saws come in 6 or 8-gage thicknesses. As the material is oil-tempered

tool steel, it is too hard to be recast successfully, and therefore has little scrape value. Discarded saws were bought at prices ranging from 0.25 to 0.50 ct. per pound and are believed to last three or four times as long in the flume as ordinary structural steel. In the flumes on 10% grade it is said that the 12-gage steel normally passes 10,000 to 12,000 cu. yd. of material before being worn out.

Cost of Flumes. For detailed costs of flume construction, see the author's "Handbook of Cost Data."

Cost of Gravel Mining. Data regarding the cost of hydraulic mining in California during the season commencing Nov., 1899, and ending July, 1900, are given by William H. Radford in *Transactions, American Institute of Mining Engineers*, vol. 31, 1901.

During this season of 9 months 655,657 miner's inches (1 inch = 1,728 cu. ft. in 24 hr.) were used for the monitors and for sweeping the bed rock at the end of the season. This water cost delivered 0.69 ct. per miner's inch. Surveys showed the amount of material washed to be 1,251,399 cu. yd., or 1.9 cu. yd. per miner's inch.

The banks varied in height from 50 to 130 ft., averaging 63 ft. The material consisted of pay gravel lying on pay rock and varying in thickness up to 8 ft., and barren top material consisting of broken rock, clay, soil, and gravel. The grade of the sluices was 7 in. in 12 ft. Long bed-rock cuts extended from the head of the sluices to the banks. These bed-rock cuts, in black slate, were constructed by hand drilling and blasting.

Electric lights permitted night work.

The ditch was 11 miles long and was cared for by two men during the rainy months and by one man for the remainder of the season.

The cost of the hydraulicking was:

	Per cu. yd.
Care of ditch, reservoir, siphon:	
Labor, $2,671; supplies, $116	$0.0022
Washing (piping), $2,401	.0019
Drilling in bed-rock cuts:	
Hand, $1,051; electric, $270	.0011
Timbering bed-rock cuts, $157	.0001
Electric lighting, $599	.0005
Sluice building and repairing:	
Labor, $1,046; supplies, $35	.0009
Blacksmithing, $644	.0005
Cleaning-up, $969	.0008
Moving pipes and giants, $899	.0007
Breaking rocks and clay, $6,125	.0049
Clearing ground for piping, $158	.0001
General expenses, watching sluices, misc., $3,089	.0025

Sluice building and repairing (continued)	Per cu. yd.
Supplies used in mine, $3,015	.0024
Taxes, office expenses, legal expenses, surveying, salaries, $4,267	.0034
Total, $27,512	$0.0220

This does not include interest or depreciation on plant.

Methods of Working Placer Gravel. The following is given in *Engineering News*, Jan. 1, 1903. The mining property in question is in California and considerable capital has been expended there for the bringing in of water which is conducted to the mine by flume and ditch a total distance of 30 miles, having a capacity of 3,000 miners' inches. The nature of the ground through which the ditch is cut, the steep slope of the hillsides and the severity of the winters cause the expense of maintenance to be rather high, aggregating about 22% of the total exploitation expenses. During the earlier years of the company's existence their water right, even in favorable seasons, never yielded over 450,000 miners' in. More recently, however, by advantageous reconstruction, this has been increased until from 650,000 to 750,000 miners' in. are obtained, according to the winter. This big supply of water — a daily average of 3,000 miners' in. during eight months — cannot be utilized constantly with profit in only one spot. For good work it is necessary to have several points of attack, thus allowing changes of water, moving of machines, clean up and other contingencies to be overcome without complete suspension of operations.

Both mines consist of gold-bearing gravels, with material of every size from pebbles to boulders of 2 to 3 cu. yd., requiring water, powder and derrick for their removal.

The bank is broken by four giants; one on the front with a head of 400 ft. and nozzle 7 to 9 in., according to circumstances; two on the left side with 150 to 250-ft. heads, and one on the right side with 500-ft. head, to break the cement.

The gravels vary in thickness from 2 ft. to 250 ft., bearing gold throughout.

Broken by the side giants, the bank is prevented from sliding too far by the front giant. The bank slides ahead as much as 100 ft. in 24 hr.

The bank being for the most part loose, this sliding is, of course, caused by the piping. For this reason the entrance of the sluice is kept at a safe distance — usually about 150 ft. away — and the front giant always settled at the head of the sluice.

The sluice is 6 ft. wide by 4½ ft. deep, with the boxes 12 ft. long. At the beginning of the last mining season there were 56 boxes, and at the end of the run 118, of which additional number

14 were at the head and 48 at the lower end. The grade is 8 in. to the box (12 ft.). The bottom is laid with blocks in the first ten boxes and boulders in the others. Two undercurrents collect the fine gold very satisfactorily.

It is estimated that between 2½ and 3 cu. yd. were moved per miner's inch of water used, at a cost of 2.7 to 3.3 ct. per cu. yd. during the season 1901–02.

A High Cost of Hydraulic Mining. In a paper published in *Transactions, American Institute of Mining Engineers*, vol. 33, 1903, W. E. Thorne gives the detailed cost of a hydraulic mining operation at Georgetown, Calif. The cost of the material moved was 18.3 ct. per cu. yd. This high cost was due mainly to the short season, the expense of buying water, the cost of building dams to impound débris from "seam-diggings" located upstream, the hardness of the bed rock and resulting high cost of ground sluices, and the generally unfavorable situation.

The bank varied from 7 to 23 ft. in depth. The bed sluices comprised 1,300 ft. of 8-ft. wide sluices and 200 ft. of 4-ft. wide sluices, varying in depth from 4.5 to 25 ft. The grade of sluices was 1 in. in 12 ft. at the upper end to 4 in. at the lower end. Sluices, including the boxes, cost from $4 to $150 per lin. ft.!

The water for ground sluices was obtained from a creek and amounted to 3,000 miners' inches continuing for 15 days of the year. The water for the giant was purchased at a cost of 0.5 ct. per hour per miners' inch. Through a 3-in. nozzle 200 miners' inches, under a head of 180 ft., were used. The average of material moved was 43.5 cu. yd. per hr. This low duty was due to the fact that the work was being carried up-stream.

The costs of supplies were as follows: Lumber, $14 to $16 per M; powder, 12 to 13 ct. per lb.; fuse, 50 to 55 ct. per 100; caps, 60 to 65 ct. per 100; iron, 3.5 ct. per lb.; nails, 3.5 to 4.5 ct. per lb. Miners received $2.50 per day of 10 hr.

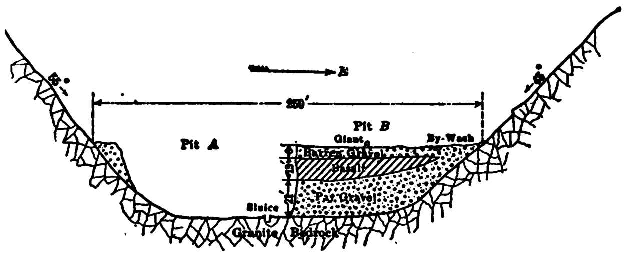
There were 7,500 cu. yd. of gravel moved at the following cost:

Water	$0.030
Labor	.015
Debris dams	.030
Moving pipe, etc.	.005
"Crevicing" and cleaning bedrock	.006
Taxes, salaries, etc.	.007
Blacksmithing	.003
Lumber	.030
Labor on sluices	.040
Powder, fuse, etc	.017
Total per cu. yd.	$0.183

Methods and Cost in a B. C. Placer Mine. The following by Chester F. Lee and T. M. Daulton is taken from the *Transactions of the American Institute of Mining Engineers*, 1916.

Ruby Creek is 8 miles long and flows in a southerly direction into Surprise Lake, British Columbia. The gravel being mined is about a mile up stream from the lake and is the stream bed or "creek gravel." The rock underlying the gravels is granitic and has taken its present form through glacial action, the alluvial material having been deposited subsequently, partly by glacial and partly by stream action, in successive flows and at widely separated times as shown by a dike of basalt about 13 ft. thick which overlies the bedrock gravel on the east side of the creek.

The gulch has steep banks and is about 250 ft. wide from rim



CROSS SECTION

Fig. 12. Cross-Section of Ruby Creek Showing Position of Gravels Being Worked by Hydraulicking.

to rim at the surface of the gravel. The depth of the gravel at the center is 42 ft.

Water. A log crib storage dam is situated 4 miles up Ruby Creek. It is 150 ft. long, 12 ft. high and 6 ft. wide at top, producing a reservoir ¾ mile long and ½ mile wide with an average depth of 8 ft. From this the water follows the creek bed 3½ miles to the intake, whence it flows into the ditch which is 8 ft. wide at the top, 4 ft. wide at the bottom and 3½ ft. deep, the grade being 8 ft. to the mile. There are 400 ft. of ditch, then 300 ft. of flume across the gulch and 800 ft. of ditch to the pressure box, which is 8 by 10 by 10 ft. From this box issues the pipe line, 2,265 ft. long, beginning with 26-in. diameter 16-gage pipe, and ending with 16-in. 14-gage pipe. The normal flow is about 1,150 miners' inches (31 cu. ft. per second) which is used through 7-in. nozzles of No. 6 Hendy giants. Also 1,000 in. come down the creek and are used as a bywash to assist in handling the heavy material. The vertical head at the pit is 250 ft. Beside the main pipe line a 16-in. line tapering to 6 in. in a

length of 432 ft. is taken out of the pressure box and used on a Cassel impulse wheel of 25-in. diameter to actuate a Sullivan 8 by 8 class WG-3 belt-driven compressor the air from which is used to drill boulders.

The sluices from the working pits are 42 in. wide by 42 in. high, set on a grade 4 in. to 12 ft. (2.77%). The sluices are double, as will be explained, and their length is 4,000 ft.

Difficulties Overcome. The obstacles to be overcome in developing and operating this property and the way they were surmounted make this operation noteworthy.

The conditions which presented difficulties are outlined below:

1. The great width of the deposit, 250 ft., which with the 42-ft. banks made impossible the working as a single pit from rim to rim.

2. In May and June the flood waters produce four times as much water as can be used, and the excess water, if carried on top of the bank, tends to undermine it and cave it into the pit.

3. Only a small grade (about 3%) was available, which offered poor facilities for dumping.

4. The boulders were large in number and size.

These problems were met as follows:

The ground was divided by a median line up the creek into two series of pits, A on the west side and B on the east, each being about 125 ft. wide. See Fig. 12. Pit A was advanced 400 ft. first and then pit B. was begun, the pits being worked alternately. After hydraulicking some hours in pit A until the pit is so full of boulders that the stream is no longer effective, the water is turned off at the valve above the workings and two men are left there to block-hole and blast the boulders. Hydraulicking is then begun in pit B and continued until the boulders obstruct the work, when they are drilled and blasted in turn, and so on.

The arrangement of sluices is such that in flood season the excess water is allowed to flow over the face of pit A into the sluice at the bulkhead and down this to where the double sluices begin opposite pit B (Fig. 13). The gates at the head of the east sluice are closed and the flood waters go through the west sluice to waste. During the time of excess water, work in pit A is suspended, but pit B can be worked without interruption, save for the time needed to drill and shoot the boulders. Without these arrangements work would have to be suspended during high water, which would be a serious drawback as the season is only about 150 days in all. When the water recedes to the point that it can all be handled through the giant and by wash, hydraulicking is resumed in the pits alternately as above described.

Only the east sluice is used for handling gravel and is fitted with gold-saving devices.

The arrangement of gates, as shown in Fig. 13, permits the

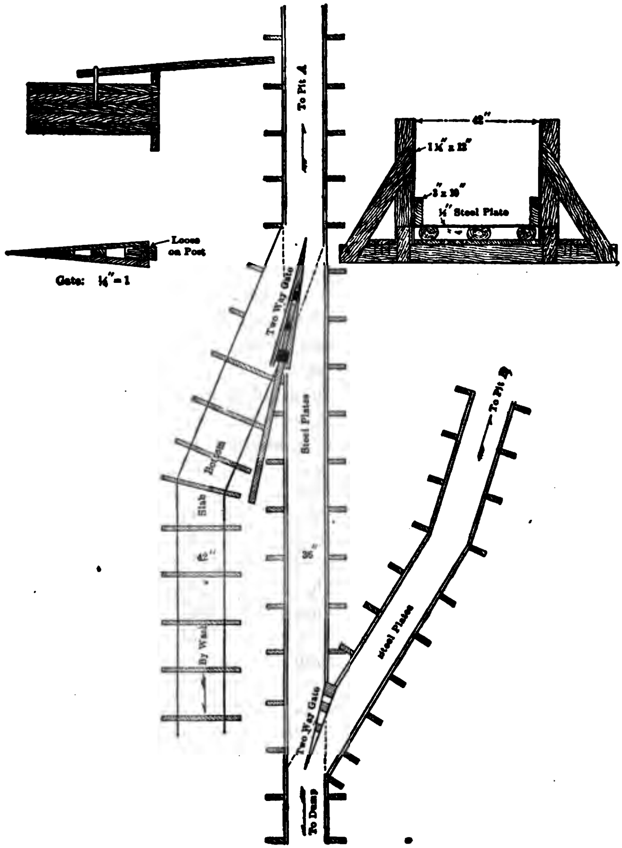


Fig. 13. Arrangement of Sluices, Details of Two-Way Gates; and Cross-Section of Gold-Saving Sluice.

gravel from either pit to be sent down the east sluice; the west sluice is used only for excess water. The upper gate, shown in detail in Fig. 13, rests loosely against the post and is raised

off the bottom of the sluice by two men throwing their weight on the end of the long lever. This relieves the water pressure and enables the gate to be thrown over. If it were not for this arrangment the pressure of the stream would make it impossible to move the gate.

The gold-saving sluice boxes, 42 in. wide, were originally paved with spruce blocks 8 by 8 by 10 in., spaced 2 in. apart longitudinally, but the excessive wear on them entailed frequent stoppages for renewals which was both annoying and expensive as the season is short and it is imperative to get the maximum use of the water during the open period. The steepest grade obtainable was 3½%, which seriously limited the amount of gravel handled. In 1914, therefore, 2,400 lin. ft. of high-carbon steel plates (0.9% carbon) were bought from the Carbon Steel Co. of Pittsburgh and substituted for wood blocks for this distance. The grade of the flume was changed to 2.77% which gave 20 ft. additional dump at the lower end of the sluice.

The plates cost $45 per ton at the mills, $108.80 per ton laid down on Ruby Creek. Plates of this sort were first used by The McKee Creek Mining Co. in this district in 1909. The plates are 12 ft. long, 38 in. wide, ½ in. thick, and are placed 2 in. apart as to their ends with a drop of ½ in. from one plate to the next. Fig. 13 shows how they are supported and held in position; 6- to 8-in. logs are sawed flat on two sides to a thickness of 4 in., and made ½ in. thicker on the downstream end than on the upstream in each 12 ft. of length. The plates are supported by these and held down by the edges of the 3 by 10-in. lining boards.

The space between plates makes an excellent riffle. The use of the plates increases the capacity of the sluice about 40% and enables angular pieces of blasted boulders 30 in. in their longest dimension to be put through as against 20-in. pieces with block riffles. Occasionally extra large boulders get into the sluice, and 5 by 2½-ft. boulders have gone through without trouble. All trouble from jammed sluices and overflows has thus been obviated.

After a season's wear and carrying 67,940 cu. yd. of gravel, the plates showed an abrasion of 1/32 in. At the end of the 1915 season, after transporting a total of 130,380 cu. yd., holes developed at some points. The surface skin of the plates is harder than the interior and where the surface becomes slightly worn deterioration is more rapid. A steel equally hard throughout is desirable for this use and the question of its production has been taken up with the manufacturers.

In 1915, 6,380 boulders were drilled and blasted and 21,955 "bulldozed" without drilling; in 1914, 23,832 were blasted,

which, taking the two years together, is a boulder for each 2.5 yd. of gravel worked. The practice is to "bulldoze" the flatter and smaller boulders without drilling, and block-hole the larger ones and pipe all the pieces through the sluice. For drilling, two Sullivan DA-19 40-lb. hammer drills are used with air pressure at 90 lb. at the compressor. The air line is 2 in. in diameter and 1,000 ft. long; two lines of 50-ft. hose ½ in. in diameter connect directly with the drills. In 1915, explosives cost 26 ct. per boulder.

In part of the ground an additional obstacle must be overcome. On the east side in pit B a dark basaltic dike about 13 ft. thick lies on top of the 21 ft. of pay gravel and is itself overlaid by 6 ft. of waste gravel. This basaltic flow is lenticular and thins out both in the upstream direction and from the center toward the east rim. It pinches out entirely 250 ft. upstream. Fortunately the basalt is friable and fairly soft, so that by putting gopher holes under it and shaking up with powder it is gradually broken through, and can be washed away by ground sluicing and hydraulicking.

In 1915 the following results were obtained:

Average number of men employed	20
Hours piping in pay gravel	978
24 hr.-in. of water on pay gravel	46,862
Total cubic yards of gravel handled	62,440
Cubic yards per 24 hr.-inch	1.33

Cost per cubic yard of gravel handled:

Labor	$0.302
Explosives	0.119
Lumber	0.007
Stable	0.009
Hardware	0.006
Licenses and rentals	0.011
Liability insurance	0.005
General expense	0.017
Total	$0.476

The property belongs to the Placer Gold Mines Co. of Seattle; G. W. Fischer, President, T. M. Daulton, General Manager; the latter has planned the work and conducted the operations since the company took over the property from the original locators in 1908, and is still in charge.

Range of Cost of Hydraulic Mining. There is a wide range in the cost of hydraulic mining. In a recently issued bulletin of the U. S. Bureau of Mines it is stated that the cost may range from 2½ ct. per cu. yd. in California under exceptionally favorable circumstances to 12 ct. or even 20 ct. at Atlin, B. C., and to 25 ct. or more in Alaska, according to the conditions of operation. Where frozen gravel is encountered and where it is necessary to elevate the gravel, costs frequently exceed 60 ct. per cu. yd. The

Bulletin gives data on work of this character from which the following has been abstracted by *Engineering and Contracting*, Oct. 18, 1916. The first figures are for a hydraulic mine in Northern California.

The season commenced in November, 1899, and ended the last of July, 1900. During this time, 655,657 miners' inches (an inch equals 1,728 cu. ft. in 24 hr.) of water were used for piping, and for sweeping the bedrock at the end of the season. From actual surveys, this amount of water washed down 1,251,399 cu. yd. of material, consisting of pay gravel lying on the bedrock, and varying in thickness from a few inches to 8 ft., and practically barren top material, consisting of mountain slide, carrying considerable broken rock, clay and soil. The banks varied in height from 50 to 130 ft., the average height being 63 ft. The grade of the sluices was 7 in. in 12 ft., the boxes being paved with block riffles 12 in. deep. Long bedrock cuts extended from the heads of the sluices to within a few feet of the banks, and were kept practically to grade as the work advanced. At first, electric drills were used on this work, but as it was found that heavy blasting shattered the rock too much, and caused slips, these drills were abandoned and hand drilling was substituted. The total cost ($27,512 for 1,251,400 cu. yd.) was made up as follows:

	Per cu. yd.
Care of ditch, reservoir and siphon: Labor, $2,670; supplies, $115	$0.00223
Washing (piping)	.00192
Drilling in bedrock cuts: Hand drilling, $1,050; electric, $269	.00105
Timbering bedrock cuts	.00012
Electric lighting	.00047
Sluice building and repairing: Labor, $1,045; supplies, $35	.00086
Blacksmithing	.00051
Cleaning up	.00077
Moving pipes and giants	.00071
Breaking rocks and clay	.00490
Clearing ground for piping (cutting brush)	.00012
General expenses, watching sluices and odd jobs	.00250
Supplies used in mine	.00241
Taxes, office expenses, surveying, salaries	.00341
Total per cu. yd.	$0.02198

The best known hydraulic mine in California, and the largest now operating in the world, is La Grange mine in Trinity County. The operating company now has a water system of 29 miles of main ditch, flume, tunnel, and siphon, 7 miles of 30-in. water-pipe line, and 14 miles of auxiliary ditch not now in use. This is supplied with all necessary reservoirs and connections for bringing the water to the face of the pit, and with the dam at the lower lake represents an outlay of approximately $700,000. Twenty-eight

men, including the boarding-house force, are employed at the mine.

The method of operating is as follows: Water is brought from the mine reservoirs in two 30-in. pipe lines and discharged against the gravel bank through giants under a head of 600 ft. Either two 8-in. or one 8-in. and two 6-in. nozzles are used at one time. These combinations require 4,000 to 4,200 miners' inches of water, and they usually empty the mine reservoirs in six hours. The water is then shut off from the pipes and the reservoirs are allowed to fill, requiring generally four hours when the full head of water is in the ditch: during this time the pipe men drill and blast the large boulders and hard pieces of cement rock in the pit.

Boulders of 1 ton and 2 tons' weight at times pass through the sluice, though such large boulders are generally blasted in order to save water. The cemented gravel is disintegrated usually before it leaves the pit, and little or none is found on the dump. At the usual rate of operation, the pipes wash down and send to the sluice 1,000 cu. yd. of material per hour. The sluice box is 6 ft. wide by 5 ft. deep and is lined with 40-lb. steel rails set transversely 5 in. apart on the bottom and longitudinally on the side and held in place by lugs and bolts.

Quicksilver is sprinkled in the upper part of the sluice every few days. The sluice is 2,400 ft. long. The great length of sluice is necessary to carry the tailings to the edge of the dump. At 1,300 ft. it branches into two parts in order to distribute the débris over the width of Oregon Gulch. Each year it is necessary to add about 50 ft. to the lower end of each branch. The amount added to the upper end varies with the slope of the bedrock and the movement of the gravel mass.

Working costs vary for different seasons from 2.8 to 3.5 ct. per cu. yd., the percentage of cost being distributed approximately as follows:

	Per cent.
Maintaining ditch	18
Washing, gravel piping	9
Sluice maintenance	25
Breaking bowlders	9
Pipe lines and giants	7½
Roads and buildings	3½
Clean-ups	1
Administration	8½
Taxes	3
Teaming	5
Boarding house	8
Various	2½

The following data, including average operating costs, relate to hydraulic mining at Atlin, B. C., for the seasons 1910 to 1913:

	Pit 1	Pit 2
Possible running time, days per season	184	180
Actual running time, days per season	154	141
Cubic yards worked per season	283,300	178,580
Cubic yards per day per season	1,540	992
Cubic yards per day for time running	1,840	1,266
Miners' inches used per day	4,500	4,250
Yards per inch per day of running time	0.41	0.30
Average depth of ground, ft.	60½	16½

Average cost per cubic yards, cents.†

	Pit 1	Pit 2
Labor	7.34	13.29
Powder	1.40	1.96
General operations	2.18	3.03
Ditch maintenance	.22	.35
General expense	.44	.70
Royalties, rental, etc.	.49	.64
Total, ct. per cu. yd.	12.07	20.01

† Boarding house included in labor. "General operations" includes supplies, teamsters, blacksmiths and other operating expense not directly chargeable to either pit. "General expense" includes traveling, offices, etc.

Costs of working gravel banks with water under pressure and elevating the material with hydraulic elevators will vary greatly in different localities. The following data concern hydraulic mining at the River Bend mine.

The River Bend mine is on the Klamath River, Siskiyou County, Cal. The water is obtained from two sources; one ditch supplies the water for the giant, the other for the elevators. The supply system includes 11 miles of ditches and 1½ miles of flume.

There are two Joshua Hendy giants with 3½-in. nozzles, which consume about 525 cu. ft. per minute working at an effective head of 90 to 100 ft. A Campbell hydraulic elevator having a 10½-in. throat and using approximately 560 cu. ft. of water per minute under an effective head of 325 ft. raises the material 46 ft. vertically. The elevator is set in a sump 10 ft. deep and at an inclination of 70°, the height of the gravel bank being 30 ft.

The following table is made from daily averages throughout the season of 1912–13. The working costs do not include administration charges.

Cubic yards of gravel washed per day	417
Cubic feet of water used per minute for giants	525
Cubic feet of water used per minute for elevator	560
Cubic feet of gravel lifted per minute	7.81
Cubic yards of gravel washed per miner's inch (giant) water	1.19
Grade of sluice, inches in 12 feet	7
Operating cost per cubic yard, not including admintration, cents	8

At the Logan mine, near Waldo, Ore., with 40 cu. ft. of water a second, 15,000 to 30,000 cu. yd. of gravel are washed per month.

Four giants are used, two in the pit and two on the tailings dump. A 20-in. hydraulic elevator with two lifts elevates the material 49 ft. The gravel is easily washed, there are no large boulders, and the operating expenses are said to be only 3⅞ ct. per cu. yd. under exceedingly favorable conditions.

Hydraulic Elevators. A hydraulic elevator is an "ejector" used to raise water and gravel. An ample supply of water and proper means for rejecting large stones, lumps of clay and débris are essential.

Elevators are generally arranged in a sump cut in the bedrock, and the gravel from the monitors is washed to this sump through a ground sluice. The elevators pick up the gravel and water and raise it from the sump to the ground sluice. Large boulders can be left in place and the bedrock around them cleaned with a small hand nozzle.

Hydraulic elevators consist of a tube into which a jet of water is introduced under pressure. The velocity of the moving jet of water acts on a larger body of water and gravel introduced at the suction end of the tube and causes it to be discharged at the other end.

Grading River Banks with a Water Jet. The following description of grading a sandy river bank is given by Taro Tsuji in *Engineering News*, Feb. 6, 1892.

The bank, 12 to 17 ft. high above low water, was graded to a slope of 2 horizontal to 1 vertical. The plant used was a 40-hp. boiler and a simple duplex plunger pump, with a stroke of 10 in., and a diameter of 5¼ in., mounted on a barge. The water was pumped from the river and delivered through a 2½-in. hose. The jet, varying in amount from 230 to 260 gal. per min., under a pressure of 140 lb. per sq. in., was played upon the bank. The earth was removed at the rate of 35 to 40 cu. yd. per hr., using 10 lb. of coal per cu. yd.

This method was economical but left the bank in a rough condition. The earth was dressed by pick and shovel.

H. St. L. Coppée, in *Transactions of the American Society of Civil Engineers*, Vol. 35, July, 1896, describes another plant constructed in 1881 for hydraulic grading of the river banks on the Mississippi. A fire pump with 16½ x 18-in. cylinders and 9-in. water plungers, having two 4-in. discharge pipes, and a 42-in. x 24-ft. boiler, were placed on a barge, 16 ft. wide by 98 ft. long by 3.5 ft. deep. The total cost of the plant was $3,679. This plant was not used.

In sluicing the bank a trench was first cut with a shovel to the required angle of slope, and in it was placed a continuous line of wooden boxes to form a trough from the top of the bank to the

water surface. A pump used for sinking piles with a water jet and mounted on a pile-driver barge, was moored near the trough and supplied its upper end with water. Earth was excavated and thrown into the trough by shovels, the water carrying to the river. This method was abandoned for work on a larger scale, the water being used to wash out the bank.

The grader used in 1882 consisted of a barge 110 ft. long by 30 ft. wide by 6 ft. deep. The pump was a Blake compound condensing, with double plungers each 16 x 24 in. The steam cylinders were 18 and 36 in. in diameter by 24-in. stroke. The capacity was 2,000 gal. per min. with a pump pressure of 160 lb. and a steam pressure of 80 lb. per sq. in. Steam was obtained from three boilers, 42 in. by 26 in. in size. The pumps discharged into a 14-in. boom pipe having twelve 4-in. openings, from which lengths of 2½-in. rubber hose lead. The nozzles were 1¾ in. in diameter.

In operation the boat was moored to the bank and the hose lead to within 8 ft. of a guide face cut in the bank. The nozzles, mounted on swivels, were each worked by three men. The slope was cut a little ahead at the upper end; the reason being that the water after discharging against the bank, ran close to the lower edge of the face, helping to undercut it. A 4-in. hose and a 1¼-in. nozzle gave the best results. Banks were graded to a slope of 2¼ to 1. Sand and light deposits were easily graded, but clay and "buckshot" resisted the jet for some time. With 3 nozzles an average of 1,300 cu. yd. was removed per day at a cost of about 4 ct. per cu. yd. Trimming was done by hand shovels.

At Bullerton in 1883, grading cost 3 to 3.8 ct. per cu. yd., 3 men being employed to each nozzle.

At Plum Point 1,800 to 4,000 cu. yd. were moved per day at a cost of 3 ct. per cu. yd.

In sand at Lake Providence Reach grading cost 2⅔ to 3⅛ ct. per cu. yd. The engineer in charge estimated from daily observations continued over a month that to excavate 1 cu. yd. of earth required a fraction less than 1 cu. yd. of water, under a pressure of 140 lb., with steam pressure at 80 lb. and a vacuum of 26.5 in. With steam pressure at 80 lb. it required 3 lb. of coal per cu. yd. of water thrown or earth removed. Shovel grading cost 30 ct. per cu. yd. At New Madrid in 1893 grading to a 3 to 1 slope cost 3.8 ct. per cu. yd.

Mr. Coppée gives the cost of a typical hydraulic grading plant with all hose and fixtures at $20,000.

Of work done in 1889 on the Missouri River for the Chicago & Alton Ry., W. R. De Witt in *Engineering News*, June 5, 1902,

states that a grading force of 1 engineman, 1 fireman, 1 watchman, 1 nozzleman, and 2 laborers graded 100 lin. ft. of bank or 800 cu. yd. of earth in a 10-hr. day, under average conditions of soil and velocity of current. Labor cost $10.25 per lin. ft. of revetment or 1.28 ct. per cu. yd., and fuel and engineman's supplies cost $2.25 per lin. ft. of revetment or 0.28 ct. per cu. yd., a total of $12.50 per lin. ft. or 1.56 ct. per cu. yd.

According to *Engineering News*, May 9, 1907, at about 40 miles below St. Louis 3,444 cu. yd. were removed by hydraulic jets, and 44 cu. yd. were surfaced by hand. The total cost was 2.5 ct. per cu. yd.

D. J. Whittemore gives the cost per cubic yard of grading a bluff on the Missouri River as 1 ct. for powder plus 1.5 ct. for labor and other supplies. The bluff was 100 to 180 ft. high and it was dangerous to employ the water jet without having at all times complete control of avalanches. This was secured by blasting down the bank after it had been partially undercut by the jet.

According to *Engineering News*, July 29, 1915, to clear the river channel of the Kaw River, Kansas, during high water, about 10,000 to 15,000 cu. yd. of earth near the east span of the Union Pacific Bridge was removed in a very short time. This work was accomplished by a gang of eight men, drilling and shooting the dirt, using just enough 40% dynamite to allow it to be broken up thoroughly. As soon as a shot had been set off at one end, a fire hose, with a 1⅛-in. nozzle, and about 80 lb. nozzle pressure, was utilized to wash the loose earth into the swift current of the river. Water was furnished by a fire engine at the end of about 1,000 ft. of hose. The river current was flowing at the rate of about 8 to 10 ft. per second, and the large pieces of excavation detached by the jet of water were quickly washed down stream by the current. The entire amount was removed in about two days' time at a very low cost.

Stripping Gravel Pits by Hydraulic Methods. The following is an abstract of an article by W. H. Wilms in the *Railway Age Gazette*, June 18, 1915.

During the past ten years there has been a rapid increase in the use of the hydraulic method of earth removal. Engineers are just beginning to appreciate the possibilities of this method of excavation, and the next decade will undoubtedly witness a still greater development and growth in hydraulic excavation. The filling of trestles on the Northern Pacific and the Canadian Pacific at a cost of from 4 to 13 ct. per cubic yard; the removal of 34,000,000 yd. of material in the regrading of Seattle, Wash.; the hydraulic construction of large embankments on the

Pacific coast extension of the Chicago, Milwaukee and St. Paul; and the more recent construction of the Fernando dam of the Los Angeles aqueduct, where about 2,000,000 yd. of earth were sluiced at a total cost of 7 ct. per yard are recent examples. The remarkable results obtained in these cases seem to be little realized or appreciated by many engineers unacquainted with this class of work.

A comparatively large field for this method of earth excavation is in stripping the overburden of gravel ballast pits and stone quarries. Conditions about a gravel pit are quite often favorable to the hydraulic method of stripping. The soil is generally a loam or soft clay that can be handled very effectively with water. A great many gravel deposits are either very close to a stream or river or underlaid with water, an ample supply of water thus being assured. The sluiced material can also be dumped in many cases into the abandoned or worked-out portions of the pit. Where this is possible, ample dumping grounds and sufficient grades for the flumes are generally assured. If the stripping is shallow, not exceeding 3 ft. in depth, and a large daily output or yardage is desired, the hydraulic method should be adopted with a great deal of caution.

Duty of the Water and Size of Installation. The amount of water necessary to move one cubic yard of material depends upon the grade of the flumes, the character of the material and to a more or less extent upon the pressure of water available. The quantity of water is of more importance than the pressure. Comparatively light grades can be used for the flumes if a sufficient quantity of water is present to effect complete suspension. Clay requires more water, greater pressure and greater flume grades to handle than ordinary loam or dirt. The amount and size of rocks, if any, also affects appreciably the duty or carrying capacity of the water. It may be said, however, that as a minimum, with ordinary loam or soft clay and flume grades of 7 to 9%, 10 cu. yd. of water are required to move 1 cu. yd. of material. As a basis for an estimate, however, it is generally not advisable to depend upon a greater percentage of spoil than 15% for loam or dirt with the usual flume grades of 7 to 9%. For soft clay and heavy, sticky loam, 10 to 12% can be considered a safe estimate where 7 to 9% grades can be obtained. The above duties are based upon a flow of 1,000 gal. per min., which is the minimum discharge advisable for hydraulicking.

In stripping gravel deposits a considerable amount of water is lost by flowing down into the gravel, which must often be considered in estimating the necessary water supply. If the top stratum of the gravel deposit is a sand or compact gravel, this

loss is generally insignificant, amounting to only 2 or 3%. If, however, the top stratum is a coarse, loose gravel, the loss from this source may be as high as 10%.

A pressure of from 40 to 60 lb. per sq. in. at the nozzle is usually sufficient for the sluicing of loam or dirt. For soft clay and some heavy loams, 60 to 80 lb. pressure is usually required. A pump having a capacity less than 1,000 gal. per min. should not be installed. A 1,500-gal. discharge would be more efficient, and for the ordinary installation is to be preferred. With such a discharge, using two nozzles, and with favorable grades, it should be possible to sluice from 450 to 700 cu. yd. of material per day of 10 hr. A crew ordinarily required for such an installation consists of one pumper or engineman; two pipemen; one assistant to the pipemen; three laborers and a foreman tearing down and erecting flumes; and one laborer on the dump.

Flumes. The water supply, the character of the overburden and the fall available to the dump determine the grades of the flumes. In the stripping of gravel pits where the excavated space is used as a dumping ground, ample grades for the flumes are generally assured. Full advantage, however, should be taken of all the fall available, a difference of only 1% in the grade of the flume effecting a great difference in the carrying capacity or duty of the water. Where the available fall makes necessary the use of low flume grades much larger quantities of water are required to effect complete suspension of the material. For stripping, grades lower than 6% should not be used. Where 3% and 4% are the maximum that can be used, the quantity of water necessary for the operation of such low grades is so great that hydraulicking fails to show any great economy over other methods. While it is true that grades as low as 3 and 4% are often used in large hydraulic mining operations, it should be remembered that in such operations the flume grades must be kept comparatively low, so that the velocity of the water will not be so great as to prevent the gold from settling in the riffles in the bottom of the flume. The object here is to use sufficient water to transport the gold bearing gravel and flume grades that will not cause excessive velocities. It is because of this fact that the carrying capacity of water in hydraulic mining is very low, the material excavated amounting to only about 2 to 6% of the water used.

Where conditions will permit, the flume grade should be at least 7%; 8 to 10% grades with an abundant supply of water are considered very satisfactory grades, and are usually obtainable in stripping operations where the material is sluiced into the worked-out portions of the pit. These remarks apply only to

box flumes. Where ground sluices are used considerably heavier grades must be used, as they are very likely to become clogged up from roots, gravel, sticks and pieces of sod. In such cases use flume boxes in these open sluices as shown in Fig. 15–8. The

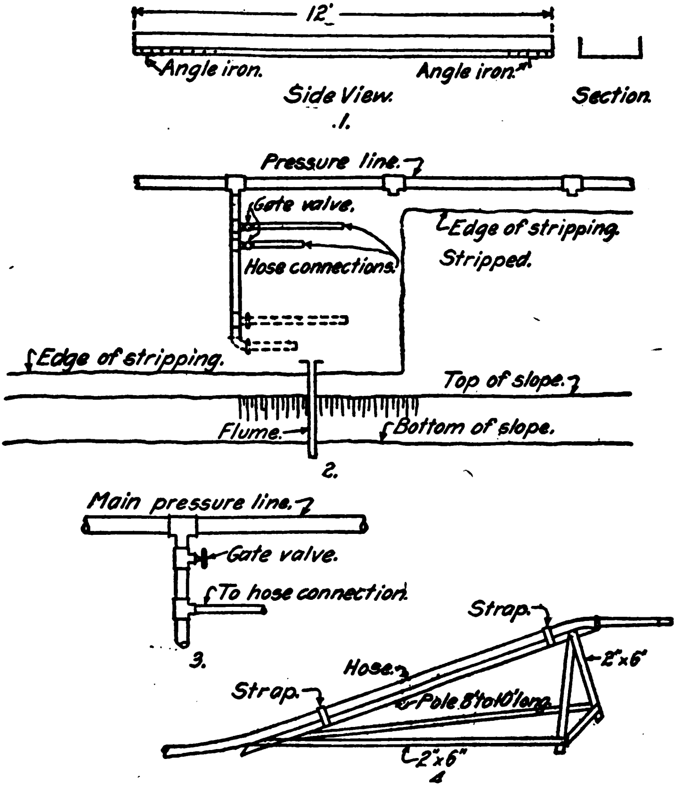


Fig. 14. Flume Construction for Stripping Gravel Pits. Sketches 1–4.

time required to place them will be but a fraction of that lost in continually cleaning out the open ditch.

Flume grades should be made as uniform as possible. A slight break in the grade will often cause clogging, especially if a sandy loam is being handled. Abrupt changes in the alinement of the

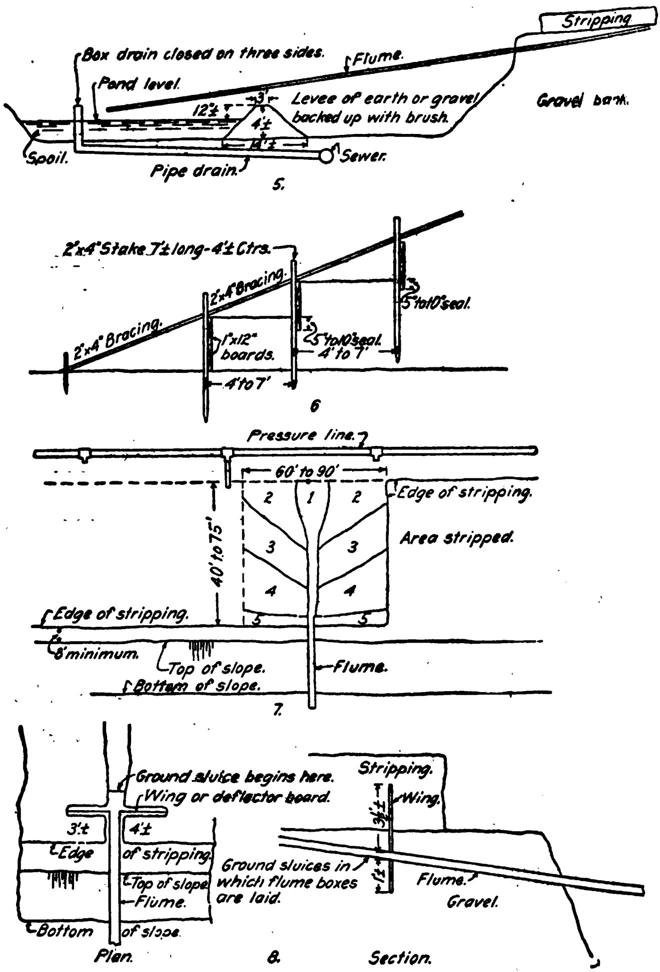


Fig. 15. Flume Construction for Stripping Gravel Pits. Sketches 5 to 8.

flumes are best made by making a break or drop in the flume grade.

Sand requires heavy grades and shallow sluices. Wide, shallow sluices should be used where the grades are light. If the overburden contains many stones and boulders deep, narrow sluices should be used. In this case, the depth of the water in the flume should be equal to the width of the flume. The width and depth of flumes depends largely upon the character of the materials as well as the water supply.

The rectangular section for flumes is generally to be preferred to the semi-circular or elliptical section. A large amount of the material carried by the water travels or rolls on the bottom of the flume. Where the circular section has been used the wear on the flume has been confined to a relatively small area in the lowest part of the section. Where stones or gritty material are present in the overburden this wear becomes excessive, the metal wearing through and becoming full of holes in a very short time. With the square or rectangular section, however, the wear is quite evenly distributed over the bottom, resulting in a much longer life of the flume.

In order that the flumes may be easily and quickly erected and taken down they should be built in sections or boxes from 10 to 12 ft. long. Both wooden and mental flumes are used. Wooden flume boxes have proven very unsatisfactory for stripping service, as they quickly become water soaked and heavy, and when dried out, check and split badly. Moreover, in the constant rehandling of the flume boxes, they go to pieces very soon. In stripping, flumes are changed many times and a flume box should be built that will not only stand the excessive wear and abrasion of the material being carried, but the rough and constant handling as well. For this service the metal flume is probably the best suited. Fig. 14–1 is a sketch of a steel box flume that has given very good service. This flume is constructed of No. 14 gage steel, and is made in sections 12 ft. long.

It sometimes becomes necessary to carry the sluiceway or flume through an intervening ridge to obtain a dumping ground for the sluiced material. If the tunnel has a heavy grade, vitrified sewer pipe will prove satisfactory. If the grade is light, however, any slight settlement of the pipe joints is liable to cause clogging. Under such conditions riveted steel pipe in lengths of 20 ft. or more has given very satisfactory results. Pipe No. 16 to No. 14 gage steel has been used for this purpose.

Stripping Shale in Illinois. The shale ledge worked by the Western Brick Co., of Danville, Ill., is covered with from 3 to 6 ft. of loamy sand and gravel, which is stripped and carried away by

means of hydraulic giants at a cost of about 2 ct. per cu. yd. From information furnished by F. W. Butterworth, the general manager of the company, the following description of the plant and of the methods of operation is given by *Engineering and Contracting*, Aug. 15, 1906.

Water is brought to the giants from the pumping station through a 10-in. pipe which is now about 4,000 ft. long. This pipe is kept extended to a point somewhere near the bank where it is tapped with two 4-in. pipe connections which extend to within from 20 ft. to 50 ft. of the working face and end in 4-in. hose carrying 2½-in. nozzles. The nozzles are fitted with adjustable needle points, which permit a variation from ½ in. to 1½ in. in the stream. The pressure at the nozzle is normally 75 lb. per sq. in., but it may be doubled when desired. The water is furnished by a compound duplex Smith-Vaile steam pump, with a 16-in. water end and 16-in. and 24-in. steam ends. The pump is located on the bank of the Vermillion River, which passes through the shale bed, and it takes steam from a 72-in. x 16-ft. tubular boiler located in a house on the crest of the river bank and some distance away. Because of the separate boiler and engine houses a fireman and engineer are required; were the engine and boiler in one building the engineer could do his own firing. It is to be noted further that the steam connections are so arranged that live steam can be turned into the low pressure cylinder; this enables the water pressure to be jumped up to 150 lb. per sq. in. at the nozzle when hard material is encountered. Normally the pump pressure is kept at 115 lb.

Two giants are worked, each operated by one man, and there are in addition a fireman and an engineer, making a labor force of four men in all. These men get $2 per 10-hr. day. On the average about 2,000 cu. yd. are moved every 10 hr. This gives a labor cost of 0.4 ct. per cu. yd. for excavating and transporting. The material is carried away in sluices, and it has been found easily possible to handle it 1,600 ft. in this manner on grades of 3%. Including costs of pumping, sluices, etc., the total cost has not exceeded 2 ct. per cu. yd. moved during the four years that the process has been used. The cost of stripping is made more expensive than ordinary excavation owing to the fact that the shale has to be perfectly cleaned by holding the stream on it after the earth has been practically all removed.

Stripping Shale in Iowa. *Engineering and Contracting*, Apr. 19, 1911, gives the following:

The shale pit is about 1,800 ft. from the Raccoon River in Des Moines, Ia. The nearest building of the plant itself to the shale

pit is the pan room, 150 ft. away. The pan room floor is 9 ft. above the floor of the pit. There is no place near the pit to which the over-burden might be moved, and it became necessary to devise a scheme for carrying the material some 1,100 or 1,200 ft. to a tract of low ground.

The hydraulic plant consists of a 14 and 20, 10¼ x 15, Worthington compound duplex outside packed plunger pump, steam for which is furnished by a 75-hp. horizontal fire tubular boiler. The pump has 8-in. suction, 7-in. discharge, 2½-in. exhaust steam, and 5-in. exhaust. At the entrance to the pump the suction line carries a vacuum chamber 12 ft. high, 8 in. in diameter, with a vacuum gage. The pump is operated at 40 revolutions per minute (80 lb. steam). That portion of the 8-in. line which runs between the river and river bank is carried on two floats and is connected to the line at the river bank by a rubber sleeve securely clamped. The 7-in. discharge line carries a gate valve at the pump and a pressure gage.

Two leads of hose are carried from 5-in. line by a siamese connection. Each lead is operated by one man. This is possible by reason of a standard to which the play pipe is rigidly attached, and which is susceptible of both a vertical and horizontal motion. Each lead of hose terminates in a ⅞-in. nozzle.

The 6-in. spiral pipe is connected to a 6 to 12-in. spiral increaser, flat on the bottom. Above this increaser are three 10-ft. lengths of 12-in. spiral pipe, which afford a reservoir to the 6-in. spiral pipe. The spiral pipe is susceptible of easy bends. There are two 45° ells in the spiral pipe line. The spiral pipe is carried through a 12-in. cast iron pipe under the C. G. W. tracks. The cast iron pipe terminates in three lengths of 12-in. sewer pipe.

The pump-house was located about 655 ft. from the river bank, and so planned that the lift from the river would amount to less than 18 ft. at extreme low water. It was decided to install a pump sufficiently large to handle the requisite amount of water without injury to the pump, at the same time insuring fuel economy. The difficult problem, of course, was the determination of the character of sluiceway which would carry away the material from the pit and place it. For only a short distance could the sluiceway be carried above ground.

An experimental line of 12-in. sewer pipe was tried with much misgiving. True to prophecy, it was impracticable, requiring long periods of flushing, and thus reducing the efficiency of the plant in that only a small amount of stripping could be done in a day. This line was one already in place, it being used as a

drainage sewer to carry off storm water, drips, etc., from the pit and from the plant. The sewer line could dispose of clay or earth in solution or gravel, but it was absolutely impracticable in the disposition of sand. The sand would settle to the bottom of the pipe, requiring hours to remove it.

Because of the large proportion of sand in the overburden, much more than is apparent from a casual observation, it became necessary to devise a sluiceway which would insure greater velocity to the effluent and at the same time agitate the sand during its flow. A 6-in. spiral pipe line was decided upon and installed. It works splendidly. This line has become clogged only twice. The plant has been in operation since May 1, and since that time to Nov. 1 there has been moved about 50,000 cu. yd. of overburden.

The following are the principal data relating to the pipe lines:

8-in. Suction Line:	
Elevation extreme low water	80.0
Elevation bottom 8-in. pipe at intersection with pump house	93.66
Elevation top of pump foundation	97.1
Elevation entrance to pump	97.6
Extreme total lift of suction	17.6
Length of suction line from pump to river bank (ft.)	655
Total length of line (ft.)	690
Grade from pump house to river bank (per cent.)	1.67
7-in. Discharge Line (Water Line):	
Total present length (ft.)	1,080
Elevation at pump	100.75
Elevation at discharge	161.0
Total lift of discharge	60.25
6-in. Spiral Pipe (Hydraulic Sewer):	
Total present length ((ft.)	1,090
Elevation of intake (station 1,065)	140
Elevation of station 729	109.67
Elevation of station 375 (45° bend)	103.6
Elevation of station 025 (45° bend)	101.45
Elevation of station 000 (outlet)	101.25

The work accomplished and its cost were as follows: Total volume of water per minute at 20 complete revolutions of each piston rod equals 428.8 gal. Total volume per day of 9 hr. equals 231,552 gal., equals 1,146.6 yd. Total effluent per day equals 1,432.5 cu. yd. Of this, conservatively, 20% is solid material, thus giving 286.5 cu. yd. overburden disposed of per day of 9 hr. Samples of effluent are taken every hour and percentage measured.

Boiler fireman	$2.25
Man at intake	1.50
One man at nozzle	2.00
One man at nozzle	1.80
Total labor per day	$7.55

Fuel, 1½ tons, at $1.50	$2.25
Oil	0.15
Maintenance and supplies, including hose, new pipe, etc.	0.85
Total cost per day	$10.80

At 286.5 cu. yd. per day, it follows that the cost of stripping and placing is about 3¾ ct. per cu. yd.

Stripping a Quarry. The following data are given in *Engineering and Contracting*, Mar. 1, 1911, regarding the method used for stripping the limestone rock at the quarry of the Mathews Stone Co., Bloomington, Ill.

The depth of quarry stone being 25 ft. an area is cleared suf-

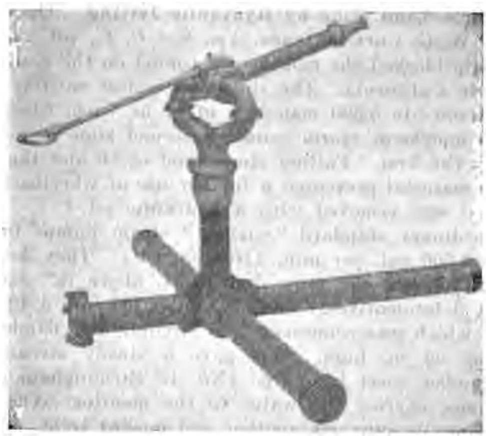


Fig. 16. Glazier Turret Nozzle Hydraulic Monitor.

ficient for a season's work, the overlying soil being each year washed into the quarry pit left by the previous season's work. To keep the new and old pits separate a dividing wall of rock is left unquarried. The floor area of the pits is about 100 x 120 ft.

The equipment employed consists of a 100 hp. boiler delivering steam at 100 lb. pressure to a compound duplex pump having 10 x 12-in. and 12 x 18-in. steam cylinders and 12 x 18-in. water cylinders, and of 7-in. pipe reduced to 4 in., with 4-in. flexible joints and a Glazier turret nozzle, Fig. 16.

In front of the quarry floor is a large hole, 30 ft. deep, and 120 by 150 ft. in extent. The overburden of the quarry is washed

into this hole by water from the hydraulic monitor. The water then overflows into another hole, and at this point the pump is located. The monitor is operated at a point about 10 ft. from the edge of the earth, one man being required. The water is directed so as to undercut the bank, and wash the earth to the sump. At the same time the seams of the rock are cleaned, and after a floor has been quarried off, the débris, such as spalls and dirt, is washed off also. The earth is hard red clay, of such a nature as to require picking for hand excavation. The overburden is removed in strips 10 ft. wide. When the monitor is moved, the pump is shut down and the engineman helps to relocate the monitor. The cost of operation is the cost of the wages of three men, and the cost of coal and oil.

Removing a Land Slide by Hydraulic Jetting. The following is given by W. G. Curt in *Trans. Am. Soc. C. E.*, vol. 24.

A land slip blocked the mouth of a tunnel on the Southern Pacific R. R. in California. The slide was almost entirely removed by wheelbarrows in 5,500 man-days of 11 hr. each, when another heavy rain and snow storm caused a second slide of as large a quantity as the first. Falling stones and earth and the soft nature of the material prevented a further use of wheelbarrows and the material was removed with a hydraulic jet.

Twelve ordinary standard "surface" steam pumps in a gang discharged 3,300 gal. per min. (16.5 cu. yd.). They were set in a line 100 ft. from the river and 15 ft. above it. Steam was supplied by 3 locomotives. The discharges led into a 12-in. pipe, one end of which was connected to a circular air chamber 60 in. diameter by 96 in. high. This gave a steady stream. From the air chamber sheet iron pipe (No. 12 Birmingham gage) in 30-ft. sections, carried the water to the monitor. The ends of the pipe were slid into one another and pushed tight, or "stove-piped." The giant was fitted with a 3 or 4-in. nozzle, according to the nature of the material. The material was carried in wooden sluices to the river.

In 9 days 9,000 cu. yd. were moved at the rate of 1,000 cu. yd. per day of 24 hr. The water required was about 2,000 gal. per min. (10 cu. yd.) at a pressure of 45 to 50 lb. Each miner's inch (1,728 cu. ft. or 64 cu. yd. in 24 hr.) moved 5 cu. yd. This is somewhat less water than is required in mining operations. The cost was as follows per 24-hr. day:

25 cords of wood at $3	$ 75
8 firemen and pumpers	20
Machinists and repairers	25
Men operating giant (high wages)	20
30 laborers	50
Total at 20 ct. per cu. yd.	$200

A steam shovel could not have been used economically, both because of the danger from falling rocks and because of the lack of room for switching cars.

Methods and Cost of Hydraulicking on the Panama Canal. *Engineering and Contracting*, Mar. 1, 1911, gives the following:

The channel of the Panama Canal for a length of about 1½ miles south of the Miraflores Locks requires the excavation of about 1,500,000 cu. yd. of rock covered with 8,158,000 cu. yd. of earth. To remove these materials by dredging and subaqueous rock excavating methods would necessitate a plant of such size that it could not be assembled for some time and would be very costly. Investigation indicated that once the rock were cleared of its earth overburden it could be excavated more rapidly by steam shovels than in any other way. Steam shovel plant was not available, however, to strip off the earth as rapidly as the progress required demanded, and, moreover, the swampy nature of the earth made it certain that the maintenance of tracks would be difficult and expensive. To meet the conditions most cheaply and expeditiously it was decided to remove the overburden by hydraulicking and pumping, and then excavate the rock in the dry by steam shovels.

By the method of excavation indicated for removing the overburden two principal operations were involved: (1) disintegrating the material and washing it to sumps by means of water jets under high pressure; (2) lifting and conveying the loosened material through flumes by means of dredging pumps. The plant required, therefore, consisted of (1) a central pumping station, (2) pipe lines and hydraulic monitors and (3) dredging pumps.

A portion of the area to be excavated was originally occupied by the bed of the Rio Grande. The river was diverted and a dike built across the south end to prevent the tide water from flowing up the old bed. Upon the completion of the dike the water remaining in the inclosure was pumped out until just enough remained to float the barges in the lowest places. The giants were operated in the immediate vicinity of the barges so as to lower them to bed rock, thus forming a sump for the suctions of each dredging pump. The regular operation of undercutting and washing the material to the dredging pumps by means of the monitors was begun, the cutting being extended until there was sufficient slope to sluice the material to the dredging units; the water would then be allowed to rise high enough to float the barges to new positions.

During the three months up to Jan. 1, 1911, that the plant described was in operation the amount of excavation was 156,125 cu. yd. and its cost was as follows:

	Ct.
Pumping station	12.5
Pipe lines	5.5
Dredging pumps	8.2
Relay pumps	0.5
Dykes	0.3
Maintenance of equipment	8.2
Power	25.2
Plant arbitrary	5.0
Division expense	1.4
Total division cost	66.7
Administration and general expenses	4.6
Total per cu. yd.	71.3

Excavating a Canal by Hydraulicking. At Seattle, Wash., part of the waterway for a canal was excavated with a hydraulic monitor. The canal was designed to have a length of about 2 miles, a width at bottom of 60 ft. and at low water mark of 140 ft., and a minimum depth of 35 ft. The following details of the work were given by C. H. Rollins in a paper read before the Pacific Northwest Society of Engineers, abstracted in *Engineering Record*, Nov. 12, 1904.

The water was obtained from a reservoir belonging to the city waterworks system, about a mile distant. The available head varied from 190 to 250 ft. Wood-stave pipes, 30 and 18 in. in diameter, and a 15-in. steel pipe at the end, were used for conveying the water to the monitor.

The material removed was of glacial formation, consisting of sand, gravel, boulders, and various clays. Light blasting was sometimes required. The quantity of water required varied between 10,000,000 and 15,000,000 gal. per 24 hr. About 3,000 cu. yd. was removed daily, using a 6-in. nozzle.

The excavated material was used for reclaiming a tract of land that was submerged at high tide. Most of the material was carried from the pit to the dump through a flume on a trestle. The minimum slope found desirable was 2.6% The flume was lined with wooden blocks, 10 to 12 in. thick, set with the grain on end. The material was spread on the dump by the use of shear boards and muck rakes.

To reach positions of the dump that could not be filled by the use of flumes, penstocks and pipe lines were tried. This latter method has the advantage of possessing greater flexibility of direction and lower cost of construction. One vertical penstock, 20 by 30 in. inside and 66 ft. high, was constructed to receive the entire discharge from the flume. It was constructed of 3-in plank, but after three weeks' use the upper 20 ft. was so worn by the discharge from the flume that it had to be lined with wooden blocks. The head used was about two-thirds of the available

head of 66 ft., and the material could be conveyed through 2,200 ft. of pipe. Another penstock sloping at an angle of 45° gave a head of 20 ft. Heavy material was distributed from this through a pipe line 800 ft. long.

Cleaning Sediment from a Reservoir. *Engineering and Contracting*, Apr. 6, 1910, gives the following:

Reservoir No. 1 of the Cincinnati, O., water works had been in constant service for over two years. It was taken out of service on March 20, 1909, and allowed to stand for 4 days in order to allow complete sedimentation before drawing the water. On March 30 the water was drawn off for a depth of 3 ft. during the night and allowed to stand during the day, when the mud was washed off the exposed slopes by hose streams under pressure of flushing pumps in the wier house. The following night the water level was again lowered to stand during the day, when the slopes were washed down. This procedure was repeated every 24 hours until April 9, when the water had become very turbid. The 30-in. drain was then opened, drawing off all the water and such mud as it carried. The deposit of mud remaining on the slopes and bottom was then disintegrated and slid to the drain opening by means of 1½-in. hose streams under heavy pressure. The depth of accumulated mud was found to be from 12 in. to 36 in. and the total amount removed was estinmated as 30,000 cu. yd. Some 35,494,600 gal. of water were wasted in draining the reservoir and 16,902,600 gal. were used for removing the mud, or about 565 gal. per cubic yard of mud removed. The cost of cleaning was as follows:

Water, at $3.28 per mil. gal.	$ 55.44
22,032 kw. electric power, at 1.1 ct.	242.36
Labor operating pumps	57.94
Labor cleaning reservoir	427.27
Total	$783.01

The cost per cubic yard of mud removed was, for cleaning proper, 2.6 ct. Charging in the 35,494,600 gal. of water lost in draining the reservoir at $3.28 per million gallons we have an additional item of $116.42, or 0.41 ct. per cu. yd. The cleaning was completed May 1, 1909.

Hydraulic Fills on Railway Trestles. Trestle No. 374, Canadian Pacific Ry., in Frazer Canyon, 231 ft. extreme height, was filled in 1896, with 148,000 cu. yd., at a cost of $5,089, or 7.25 ct. per cu. yd., including cost of plant, explosives used on cemented gravel, labor, etc. Fifty per cent. was cemented gravel, 30% loose gravel and 20% large boulders, which were removed with a derrick. The plant consisted of 1,450 ft. of sheet steel 15-in. pipe, 1,200 ft. of sluices or flumes, 3 ft. wide x 3 ft. deep;

one No. 3 "giant" monitor with 5-in. nozzle, and a large derrick driven by a Pelton water wheel to handle boulders. Piping head was 125 ft. Sluice boxes were laid on a 11% grade for the first 430 ft. and 25% the rest of the distance, 700 ft. The boxes were partly supported on high trestles. The sluices were paved with wood blocks on the light grades, and old railway rails on the heaviest to protect them from abrasion. The entire force were common laborers, except the pipeman and the foreman, working as follows: One man at "giant," one at head of sluice, two along sluice keeping large stones moving, three at outlet of sluice directing stream, and building small retaining barriers of brush or old ties and a foreman who was also a carpenter, total 8. The water used was 20 second-feet or 1,000 miner's inches, the duty performed being 1.77 cu. yd. gravel moved per 24-hr.-inch, which is equivalent to about 980 cu. ft. of water per cu. yd. excavated, but it is claimed that if the head had been about 400 to 500 ft. and the gravel all loose, "the duty of the water would have been increased fourfold." Note, however, that amount of water actually used agrees closely with Mr. Radford's placer mining experience above given.

The time of the whole force occupied in making this fill was:

Sluicing	95.3
Removing boulders from pit	50.4
Repairing flume and plant	13.5
Total days of 10 hr.	159.2

The total number of yards moved divided by the actual working time when sluicing was in progress gave an average of 738 cu. yd. per 10-hr. day. The cement gravel and boulders, it will be seen, greatly delayed work. At Chapman's Creek, in 1894, the railway company made a similar fill of 66,000 cu. yd., at 4.34 ct. per cu. yd. for labor, and estimating 20% of the first cost of the plant as chargeable to this job, the total was 7.15 ct. per cu. yd. The actual labor cost of sluicing was only 1.78 ct. per cu. yd.

Mountain Creek trestle was filled in 1897–8 with 400,000 cu. yd. This trestle was 10,086 ft. long, with an extreme height of 154 ft. The fill was carried up on a 1.5 to 1 slope. For the first 60 days, of 10 hr. each, the output of the plant was nearly 1,100 cu. yd. a day, and during that time the cost was:

Mattresses	$1,370.79
Labor sluicing	1,195.96
Maintenance and repairs	678.90
Superintendence and tools	385.05
Total, 65,000 cu. yd. at 5.59 ct.	$3,630.70

About 2.4 ct. per cu. yd. should be added for the proportionate part of the first cost of plant.

The water was delivered to the "giant" under a head of 160 ft., the nozzle being 5½ in. The volume was therefore 15.75 second-feet. The ratio of water to gravel was 19 to 1. The sluice boxes were laid on an 8% grade. The water supply was brought two miles in a flume, 4 ft. wide x 2 ft. high, on a grade of 20 ft. to the mile. The entire plant, including roads, camp, stables, flume, 1,200 ft. of pipe line, 600 ft. of sluice boxes, etc., cost $10,038.

Latham Anderson, in a paper published in the 1901 volume of the "Association of Engineering Societies," gives some abstracts from the "United States Geological Survey Report," 1896–97, Part IV, which we can here repeat to advantage in illustrating what has already been done in the way of economic earth excavation.

Northern Pacific R. R. Trestles. During 1897, in eight high trestles, 377,000 cu. yd. were moved for about 4.8 ct. per cu. yd.

Sluicing and building side levees	3.85
Hay used in levees	0.09
Tools	0.08
Lumber and nails	0.22
Labor building flumes	0.44
Engineering and superintendence	0.11
Total ct. per cu. yd.	4.79

In the above work water was carried by gravity. In one case pumping was resorted to, and 42,250 cu. yd. were moved for 13.5 ct. per cu. yd. The plant was inexpensive. One No. 2 "giant" costing $95, with 300 to 1,000 ft. of light sheet-iron pipe costing 27 ct. per foot, and lumber for sluices, which may be re-used in moving from place to place, constituted the outfit. Five to six men were required to erect and operate the plant.

This work was done in a dense forest, where the ground to be sluiced had to be cleared. In the one case, above referred to, where pumping was necessary, the cost was:

Sluicing and building levees	10.81
Hay used in side levees	0.21
Tools	0.14
Lumber and nails	0.12
Labor building flume	0.14
Coal used in pumping	1.87
Engineering and superintendence	0.20
Total, ct. per cu. yd.	13.50

In all cases the sluice boxes were paved with square 3-in. blocks laid so that the ends would receive the wear due to the gravel. It was found that grades of 7%, preferably 8%, were

best where there was large gravel or rock to be moved. The flumes were made in the most temporary manner of 1¼-in. lumber, the boxes being 16 to 18 in. square. Hay was used for building up the side levees of the embankment and easily moved baffleboards to deflect the main current from striking the levees. The waste water was taken off through a waste box. Several gates were provided in the flume so that coarser material might be deposited where the finer is found to be in excess.

The following shows the range of costs:

Trestle No.	Cu. yd.	Ct. per cu. yd.
164	18,300	8.21
165	6,200	16.58
167	24,500	14.00
170	30,800	8.75
172	4,300	10.55
173	9,700	6.23
178	2,100	13.25
179	19,800	9.31
182	53,600	3.80
184	96,650	4.34
185	800	30.24
186	51,600	7.02
189	158,100	5.19
190	128,800	6.11
191	42,250	13.50

It will be noted how the cost per cu. yd. decreases as the number of cu. yd. to be moved increases. A railway trestle can thus be filled without interfering with traffic, and when filled there is no settlement of the embankment. Photographs of this work, as well as of similar work on the Canadian Pacific Railway, are given in Schuyler's excellent book on "Reservoirs."

Further data on filling trestles by sluicing are given in *Engineering News*, Oct. 12, 1899. There is nothing special in the process except the manner of forming the outer dam or levee around the top of the embankment. This is built of alternate layers of tough marsh hay or straw and earth. The hay is shaken down loosely by a man walking along the edge, and the earth is spaded from inside. This hay protects the levee from erosion during construction, and, as the seeds germinate, a sod is formed.

Banks of this character are remarkably solid and show no signs of settlement. One of the great advantages possessed by this process is that the tracks are not occupied by work trains. The only disadvantage connected with the method is the slow speed of construction. A crew of five men and one giant will place between 500 and 1,500 cu. yd. per day. If water is abundant, however, several crews can be worked.

E. H. McHenry states that the cost of filling about 30 trestles

on the Northern Pacific Ry. has averaged for several million yards about 6 ct per cu. yd., ranging from 1.5 to 25 ct.

Cost of Sluicing a Highway Embankment is given in *Engineering and Contracting*, Oct. 9, 1907, as follows:

In connection with the building of a dam in Newaygo county, Mich., a wagon road had to be changed. A cut was to be excavated and an embankment made. The cut for the most part was a side hill cut, the grade descending 15% toward the river. The material had to be deposited 40 to 50 ft. below the cut, and from 100 to 500 ft. distant. In all, 20,000 cu. yd. were sluiced; but a record of the cost of only the first 3,000 cu. yd. was kept.

For this work there was installed one 3-in. Gould's rotary fire pump. This was set up on the river bank and a 3-in. pipe line run up the bluff. The pump was driven by a 30-hp. motor. One 3-in. hose and a 1¼-in. nozzle were used. The trough for transporting the water and earth was of iron, 20 in. wide with 5-in. vertical sides, and was laid on the ground as the work progressed upward on the 15% grade. The earth was held to the slopes of the embankment below by means of brush, poles and straw.

The nozzle was clamped to a 2 x 10-in. plank, about 12 ft. long, and this plank was pivoted to a standard similar to the jack used by a wagon wheel painter, only heavier. With this arrangement one man handled each nozzle, and was assigned one helper for moving hose and keeping troughs in shape near the nozzle.

The material excavated was sand and gravel. The pump and pipe line were set up in two days by two men. Four men sluiced the 3,000 cu. yd. in four days, or 750 cu. yd. per day. The cost of plant was as follows:

3-in. Gould pump	$ 200
500 lin. ft. steel trough 50 ct. per lin. ft.	250
3-in. pipe line fittings	250
30-hp. motor	450
Total	$1,150

The labor costs were:

Setting Up Plant:	
2 men 20 hr. at 20 ct. per hr.	$ 8
Sluicing:	
4 men 40 hr. at 20 ct. per hr.	$32
1 man 40 hr. at 25 ct. per hr.	10
Dismantling Plant:	
2 men 10 hr. at 20 ct. per hr.	$ 4
Total labor	$54

The man at 25 ct. an hour ran the motor and attended to the pump.

The power to run the motor was furnished by an electric power plant, the charge for the power being 1 ct. per kw. hour, a low price.

Summarizing we have the following cost per cu. yd. on this 3,000-yd. job:

Installating and dismantling plant	0.4
Labor sluicing	1.4
Straw, oil, water, etc.	0.1
Electricity at 1 ct. per kw. hr.	0.3
Total, ct. per cu. yd.	2.2

Since the first cost of the plant was only $1,150, a charge of $6 a day for plant rental would exceed 100% per annum, even though the plant were idle one-third of the time; but $6 a day is only ¾ ct. per cu. yd.

The Sheerboard Method of Retaining Wet Earth. *Engineering News*, Sept. 5, 1914, gives the following:

The sheerboard method of construction is largely used in the building of hydraulic fills and dams. Under most conditions it is a cheaper and more effective way of retaining the water-borne earth than any other method. Under this plan the material is retained by two or more bulkheads or "sheerboards," made of plank laid horizontally on edge and retained by sticks. On light work, two 1 x 12-in. boards nailed to 24-in. stakes about 7 ft. long are sufficient. The stakes should be about 4 ft. apart. After the material is carried up to the top of the first row of sheerboards, a second row is built from 4 to 7 ft. back of the first. The bottom of this top sheerboard is placed from 5 to 10 in. below the top of the lower bulkhead to prevent bulging and flowing out between the bulkheads. The amount of "seal" necessary depends upon the nature of the material being handled. In ordinary loams, 6 in. has proven effective, while in fine clay and sandy loam, 10 in. is often necessary. As many sheerboards are built in this manner as are necessary to build up to the desired height. By this method the water is taken off through spillways that lead to pipe drains or natural drainage courses.

For full descriptions of this method see the description of the grading of Westover Terraces at the close of this chapter. See also Chapter XV on hydraulic dredging.

A Small Sluicing Job. The hydraulic method was adapted in a Southern Michigan village in 1914 for replacing and compacting portions of the head-race dike of a gristmill which had been washed out. This head-race winds along a low bluff on one side of a flat valley. Gravelly sand along the top of the bluff was available for the embankment. As it was necessary to install a pump so that this material might be compacted with water, it

was decided to make the fill by the hydraulic method. The following data on this work are taken from an article by William G. Fargo in *Engineering News-Record*, Feb. 14, 1918.

A 3-in. rotary fire pump was taken from the mill. Five hundred feet of old 2½-in. hose and nozzles were borrowed from the village fire department. Two sets of troughs were made as shown in Fig. 17, so one could be moved forward without stopping the work. The embankment was first brought approximately to the

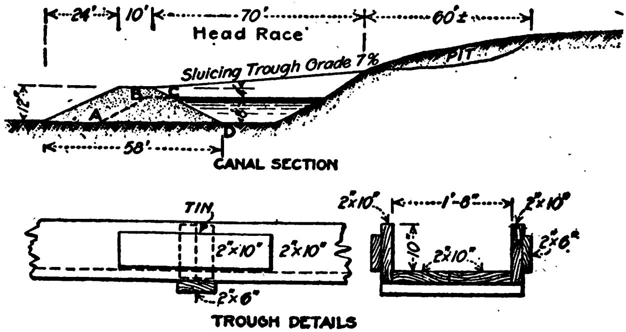


Fig. 17. Method of Building Small Embankment with Flume.

outline A, B, C, D, and water let into the canal so the mill could be started. The spillway in the meantime was inclosed in a coffer-dam. The use of troughs for transporting filling material across the race made it unnecessary to provide a bridge for teams or to defer the turning of water into the canal. The amount of the fill handled by this simple hydraulic equipment was only 670 cu. yd., which was placed and sloped in 5½ days of 10 hr. each. The cost was as follows:

Troughs, 156 linear feet or 1,500 ft.b.m. @ $20.00 M, less salvage	$ 30.00
1 — 3-in. pump on hand, no charge.	
500 ft. of 2½-in. hose, on hand, no charge.	
Traction engine, 10 hp., with man, 6 days @ $5	30.00
Labor, 5 men, 2 days installing and dismantling @ $2	20.00
Labor, 5 men, sluicing 5½ days	55.00
Coal, 2,500 lb.	6.25
Proportion supervision	15.00
Total at 23.3 ct. per cu. yd.	$156.25

If the work had involved four times as much fill, adding the proportional labor, fuel and engine rental charges, the cost per cu. yd. would have been 16 ct.

Sluicing Earth into a Dam on the Snake River. Three dams of the hydraulic-fill and rock-fill type on the Snake River in Idaho, are described by James U. Schuyler in *Transactions, American Society of Civil Engineers*, vol. LVIII. The earth fill amounted to 58,000 cu. yd. in one, 62,850 cu. yd. in the second and 48,000 cu. yd. in the third; 114,250 cu. yd. of rock were used in the three dams. A wooden core wall was built of 2-in. plank from the bottom to within 6 ft. of the top, the plank being laid horizontally, breaking joints, and being spiked to 3 x 6-in. uprights placed 2 ft. apart from center to center. The base of this wooden partition was embedded in concrete, which filled the trench to above the line of the bed rock, and formed a tight bond with the rock.

The principal part of the hydraulic-filling for the north dam was delivered from the north side of the river through a flume, in the upper end of which a receiving box was placed where the earth was dumped from wagons into a trap. Water pumped from the river washed it down to the dam. The earth was loaded into the wagons by an elevating grader. The water used was about 1 cu. ft. per second, delivered by a No. 4 centrifugal pump. The lower end of the flume discharged along the upper side of the wooden core wall, first filling the voids in the rock-fill and then extending up stream in the water, assuming a very flat slope of 6 or 7 on 1 under the water line. Great difficulty was experienced for some time in stopping a few leaks through the wooden partition, and considerable earth filling was carried through the dam and lost. This may have been due to the settlement of the cribs under the weight of rock, or to imperfect joining with the bed rock. The necessity for doing much of the work in freezing weather was one of the causes of the serious difficulty encountered in making the hydraulic fill. Layers of frozen earth were formed in the embankment and these subsequently thawed out when the water was allowed to rise against the dam, treating alarming settlement in the earth next to the rock-fill. This alarm was due to the extent of the disappearance of the earth-fill below the water line along almost the entire length of the dam, and the volume of leakage through the dam when the water reached its normal height. This leakage was not definitely measured, but it was estimated at one time at more than 6 cu. ft. per second. In an ordinary earth dam such leakage would necessarily be fatal. In this case it was never a source of actual danger, and only resulted in the loss of 2,000 to 3,000 cu. yd. of earth filling (possibly less), before the leaks were finally closed with fine gravel brought in a barge from a few miles above.

The contract prices for these dams were: Dry earth in em-

bankment, 27.5 ct. per cu. yd.; and sluicing earth, 37.5 ct. per cu. yd. These prices were high for several reasons, namely the high cost of fuel, the scarcity of earth in the neighborhood of the dams and the high price of labor.

Dam at Tyler, Texas. This earth dam was built in 1894 by the hydraulic method. The embankment is 32 ft. high, 575 ft. long, and contains 24,000 cu yd The water for hydraulicking was pumped through a 6-in. pipe from the city pumping station by a Worthington steam pump of 750,000 gallons daily capacity.

In beginning the dam a trench 4 ft. wide was excavated through the surface soil to a depth of several feet, and was filled with selected clay sluiced in. Then low sand ridges or levees were thrown up at the toes of the proposed dam and carried up as the dam progressed, the clear water being drawn off from time to time.

In loosening the material for the dam a water jet was directed by an ordinary 1½-in. nozzle attached to a 2½-in. hose, and the pressure was 100 lb. per sq. in.

The washing was carried into the hill on a 3% grade, which soon gave a 10-ft. face, increasing gradually to a 36-ft. face. The jet, of course, was directed at the foot of the face, undermining the material. The cost, including plant, labor, etc., was 4.75 ct. per cu. yd. excavated.

The material was transported in a 13-in. sheet-iron pipe put together stove-pipe fashion, with loose joints. The pipe extended from near the face of the bluff, where the jet was operating, across the center line of the dam. When the end of the dam nearest the bluff reached full height the pipe was raised on a trestle to give it grade for transporting the material to the opposite side. The material transported varied from 18% in clay to 30% in sand. The volume of water pumped, computed on a basis of these percentages, was less than 20,000,000 gallons. The entire cost of this dam was $1,140, which is a marvel of cheapness and illustrates what can be done using the hydraulic method. It should be noted here that dam building should never be attempted with earth sluice ditches in place of pipes.

La Mesa Dam, California. This dam is described in Schuyler's "Reservoirs" where excellent photographs are given of the work in progress. In this case, no "giants" were used, most of the material being loosened with plows and carried with scrapers to ground sluices or boxes in which the water ran that carried the material to the dam site; 38,000 cu. yd. were thus handled, some of which was transported 2,200 ft. in the sluices, and 11.5 acres were stripped to a mean depth of 2 ft. to get the material. This shallow cutting made the dam cost three or four times what

it otherwise would have cost. The dam was a rock-fill with an earth core washed to place, as described. From the main water supply ditch, laterals were cut so as to divide the area to be excavated into zones 50 to 100 ft. wide by several hundred feet long, leading toward the dam on 6% grade.

Where the grade of ditches was 25% or more, they eroded their own banks, and required no assistance from picks or plows. After these ditches had secured their load of gravel, they delivered to a 24-in. wooden-stave pipe, which carried the material to the dam site. About 2,000 ft. of this wood pipe was used, the first cost of the pipe being 90 ct. a ft. It was made in 12-ft. sections, loosely placed together, and connected by strips of canvas wound around these butt joints, and held with a tarred rope tourniquette. The pipes wore rapidly. Sheet-iron or open-wood flumes would be preferable.

During the first 30 days of 24 hrs. each, 700 cu. yd. a day were moved. The solid material was 3.3% of the water; 27 to 45 men, working in 8-hr. shifts, were employed. The cost of loosening was the main item.

The San Leandro Dam (Cal.). This dam, built in 1874–5, contains 542,700 cu. yd., of which 160,000 cu. yd. were deposited by the hydraulic method at a cost of ¼ to ⅕ the cost of moving earth by carts or scrapers. The water was brought four miles in a ditch, and the sluiced gravel was conveyed in a flume lined with sheet iron, laid on a 4 to 6% grade.

Hawaiian Dam Built by Sluicing. James D. Schuyler in *Transactions, American Society of Civil Engineers*, vol. LVIII, gives the following:

A dam on the Island of Vahn, Hawaii, was of the hydraulic and rock-fill type, being 98 ft. high and 580 ft. wide on the base and 25 ft. at the crest. Ground-sluicing was the method used, the soil being plowed and pushed into a stream of water, which carried it to the dam. The work of loosening and delivering the soil to the sluice was done by contract for 8 ct. per cu. yd. The cost of distributing averaged 3 ct. per cu. yd., making a total of 11 ct. In all 141,000 cu. yd. were excavated; 100,000 yd. were handled by steam plows and a "crowder," a V-shaped scraper pulled by a traction engine, while 41,000 cu. yd. were handled by men with picks and shovels.

A Small Hydraulic Fill Dam. *Engineering and Contracting*, Jan. 13, 1909, gives the following:

A dam built for a small reservoir of 2,000,000 gal. capacity, was located in California. The material for the dam was sluiced into place with a No. 1 giant with 2 and 2½-in. nozzles. This giant complete cost $70. A 4-in. centrifugal pump furnished the

water. The water was available under a 40-ft. head and by means of a direct-connected 30-hp. motor the pressure was increased to 45 lb. per sq. in. The consumption of water was 425 gal. per min.

The material washed down was obtained from the reservoir site, so as to increase its capacity. This material was a decomposed porphyry that had to be blasted. The method of making the blast holes in the rock was novel, as the holes were bored to a sufficient depth for blasting with the giant or monitor. The blasting was done with dynamite.

The method adopted for making the embankment was as follows. Two flumes were built on the edges of the dam site and allowed to flow inward. In this way the gravel and sand were mixed, and the fine material had a tendency to collect at the middle of the dam, while the coarse formed a good protection to the outside of the dam. The embankment was made exceptionally wide, so that the capacity of the reservoir could be increased at a later date. The resulting dam was well packed, and required only a slight riprapping on the upper slope. The embankment contained 7,600 cu. yd.

Work was carried on about 15½ hr. each day and the job was finished in 80 days with 5 to 7 men working with one team. About 31,620,000 gal. of water were pumped, equal to about 156,000 cu. yd. of water, to excavate and transport 7,600 cu. yd. The volume of material moved was about 5% of the volume of the water. For each 4,175 gal. of water pumped 1 cu. yd. of earth and rock was excavated and put into place. For each kilowatt hour of power consumed about 2,100 gal. of water was pumped. In addition 3,200 lb. of dynamite was used in blasting.

The foreman was paid $3.00 and the laborers $2.25 per day. Electrical power was paid for at the rate of $60 per hp. per year, and 40% dynamite cost 13 ct. per lb. Teams are rated at $5.00 per day.

The total cost of the work, exclusive of general expense and any charge for plant, was as follows:

Foreman	3.1
Laborers	14.2
Team	5.2
Power	4.2
Dynamite	5.5
Incidentals	2.0
Total, ct. per cu. yd.	34.2

Handling Hydraulic Fill on the Piute Dam. Hydraulicking material for this 95-ft. earth dam required four seasons. The work, finally completed in 1914, is described by Joseph Jenson in *Engineering Record*, July 17, 1915.

Before hydraulicking was started the up stream toe was built up 53 ft. by hauling with wagons and dump boards in the usual manner from a deposit lying too low to be available for sluicing. The first trestle was built from end to end of the dam 100 ft. inside the down stream toe. Branch trestles were built latterly from the main trestle which had a 4% grade. On these steel-lined sluice boxes were built of 2-in. plank and ¼-in. carbon steel plates. Butt joints between sections of sluice boxes were secured by lapping the steel plates from one 14-ft. section to another. Each of these sections was so arranged that it could be handled as a unit without knocking down.

As the fill proceeded, side and cross braces were taken off so that only the posts and caps of the trestle remained standing in the fill. After the dam was brought to the height of the first trestle, smaller trestles were used.

The lifts were made by stages of 10 or 12 ft., as it was found that small trestles were more economical of both timber and time.

Sluicing operations began along the lower toe, which was kept built up of solid material to a height of 4 ft. above the surface of the settling pond. The lower toe was built to a 1 on 2 slope, but, as weight was added, the saturated material forming the dam squashed out. The width so added was taken advantage of later to build the dam up to a 95-ft. elevation instead of only 90 ft. as originally planned.

During the second season and until the completion of the dam, a heavy dry bank was hauled in along each edge and the regular slope maintained. The last 5 ft. of fill forming the crest of the dam was also hauled in dry.

The flow of water used for sluicing varied from 4 to 6 cu. ft. per second, depending on the elevation and consequent pressure at the giant nozzle. The giants used were No. 1 Hendy giants with 4-in. diameter nozzle tips. Best results were obtained when the sluice bank was distant from the giant setting from 50 to 150 ft. At nearer settings it was found more difficult to regulate the amount of earth carried down to the sluice flume in such a manner as to utilize the full carrying power of the water, and to keep the sluice boxes from clogging. At greater distances the eroding power of the jet was lessened, and the system, therefore, operated under light load. It was found advantageous to keep a boosting jet near the head of the sluice boxes. This was obtained by attaching a length of 3½-in. fire hose to the pipe line back of the giant, with a fire nozzle attached and fastened immediately over the sluice box, with the jet directed slightly downward and along the direction of the sluice box. This was found particularly efficient in giving the very coarse material a rolling rather than

a sliding motion along the sluice box bottom. By this device it was possible to handle rocks weighing 50 to 60 lb. without difficulty.

Tangents Better than a Curve. Another item which proved rather interesting was the manner in which turns in the sluice box should be made. It was at first assumed that these turns ought to consist of long smooth curves. These, however, gave

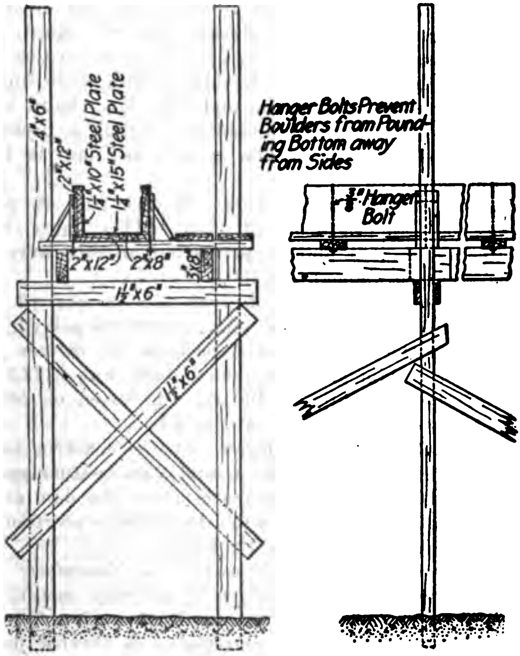


Fig. 18. Hanger Bolts to Prevent Boulders from Pounding Bottom Away from Side.

considerable trouble, even when the grade was somewhat steeper, by the rougher material slowing up and thereby causing the boxes to clog. Careful observation showed that this was due to the added friction caused by pressure against the side of the box. It was also observed that when this rough material was allowed to impinge against a vertical surface set obliquely to the direction of the motion that the larger rocks would rebound from the surface, then return to the side with a series of decreasing

impacts and velocities before they finally assumed their altered direction with an accelerating motion. When the turns were made with a series of tangents 14 ft. long, each one making an angle of about 150°, i.e., a 30° offset with the preceding, the clogging tendencies were almost entirely overcome.

The sluice banks on the east side contained a large amount of rocks and boulders. These would eventually cover the borrow pit area to such an extent that it would become impossible to penetrate the surface with the stream from the giant. It was, therefore, necessary to keep a force of men and teams at work clearing away these rocks and boulders which were dumped on the downstream slope of the dam and were later hand laid, thus forming a very efficient riprap and serving as a protection of this slope against weather erosion as well as from the tramping of sheep and cattle.

The 257,600 cu. yd. of hydraulic fill cost 20.9 ct. per yard, estimating 100% depreciation of plant. This figure would be reduced to 18.7 ct. if a plant depreciation of 50% were charged off. (The plant cost about $11,300.)

The dry fill of 186,500 cu. yd. cost 47.8 ct. per yd. Riprap on the upstream slope, 8,540 cu. yd., cost $1.905 per yd., and the 3,177 cu. yd. on the downstream slope cost 72.9 ct. per yd. The total cost of the dam and contiguous work was $322,311. The unit cost of the total fill, 444,100 cu. yd., based on 50% plant depreciation, amounted to 30.9 ct. per yd.

Hydraulic Fill Dam in Michigan. In the construction of the hydroelectric development of the Grand Rapids-Muskegon Power Co., Michigan, 104,000 cu. yd. of material for the dam and 20,000 cu. yd. for a bridge approach were sluiced into position, according to *Engineering Record*, Oct. 19, 1907.

The bridge approach fill was started in November, 1906. A 3-in. Gould rotary fire pump, driven by a 30-hp. motor, supplied water from the river to a 1¼-in. nozzle through a line of 3-in. pipe and hose. The loosened material was carried down into the fill in a sheet-iron flume, 20 in. wide at the bottom and 5 in. high, laid at a grade of 15%. The pump and pipe line were set up by 2 men in 2 days.

In five days of 10 hr. each, 4 men and 1 foreman placed 3,000 cu. yd. at a labor cost of $42 or 1.4 ct. per cu. yd.

These pumps were not adapted to the hard continuous service required in sluicing operations and were out of commission about 50% of the time. The pumps were designed to deliver 1,125 gal. per min. each. The nozzles used were 1¼ to 1½ in. in diameter. The pressure at the nozzle was 60 to 80 lb. per sq. in.

The material was mainly sand containing hardpan and clay. With the pressures attained the jets could not loosen the latter materials. The average height of the bluff was 30 ft. The greatest distance the material was moved in flumes was 800 ft. The flumes were laid on grades ranging from 5 to 9%. With grades of less than 6 or 7% it was necessary to have a man at each 50 ft. of flume to prevent stoppages. The costs were as follows:

Cost of Equipment and Materials:	
Two 6-in. Rumsey underwriters rotary fire pumps (new)	$ 840.00
Two 6-in. Gould underwriters rotary fire pumps (second hand)	750.00
430 ft. 10-in. No. 16 gauge spiral riveted pipe, cost 60 ct. a foot when new, second-hand, 45 ct.	193.50
400 ft. 8-in. wrought-iron pipe and fittings (new)	436.45
414 ft. 6-in. wrought-iron pipe and fittings (new)	272.00
120 ft. 4-in. wrought-iron pipe and fittings (new) material bought second-hand including all fittings for the 10-in. line, also 6-in., 8-in. and 10-in. fittings for pumps, 150 ft. 4-in. rubber hose and nozzles; 350 ft. of 30-in. No. 12 gauge flumes used two months on another project	800.00
500 ft. No. 12 gauge 30-in. flume	250.00
Pulleys, belting 3-in., cotton mill hose and other sundries	200.00
Total plant	$3,741.95

Charge 50% of this total to next job, leaving $1,875 to be divided by 104,000, which was total number of cu. yd., gives the proportionate cost of plant as 1.8 ct. per cu. yd.

Labor and Supplies:	
Labor from pay roll, total	$3,774.61
Teams (removing stumps and stone, handling flumes and trestle timber)	248.56
Straw	18.00
Oil, waste, pumps repairs and sundries	118.83
Total labor at 4 ct. per cu. yd.	$4,160.00

Killowatt hours of power measured at meter at Big Rapids dam 18 miles from Croton	138,008
Deduct for line and transformer losses and for power used for other purposes at Croton	46,008
Net power used by pumps of sluicing plant	92,000

92,000 kw.-hr. at 1 ct. = $920, which divided by 104,000 equals 0.9 ct. per cu. yd.

Summary of Cost:	
Plant depreciation	1.8
Labor and supplies	4.0
Power at 1 ct. per kw.-hr.	0.9
Motor rental	0.1
Total ct. per cu. yd.	6.8

Cost of Plant and Operation, Lyons Dam, Mich. The material was mainly from a 10-ft. bed of sand and gravel overlying a tough clay bluff, about 70 ft. high. Several expensive trestles were required to carry the flumes to the dam site. These trestles and the difficultis caused by ice (the sluicing was started in November, 1906) materially increased the cost of the work. Much of the bank froze and had to be blasted. The cost of the plant and its operation is given in Table 2, which is taken from *Engineering Record*, Oct. 26, 1907.

Labor and Coal Cost:	
Setting pumping plant, labor on house for same, placing pipe, etc.	$ 531.38
Labor at power house	577.20
Labor at pump house	486.60
Sluicing labor, building flumes and trestle	3,117.50
675 tons of coal	1,687.50
	$6,400.18
Earth moved from pit, 23,400 cu. yd. $0.273 per cu. yd. for labor and coal.	
Cost of Sluicing Plant at Lyons Dam:	
2 — 6-in. rotary fire pumps, new; 1 — 5-in. rotary fire pump, second-hand	$1,300.00
Pipe fitting, trough, etc.	1,200.00
Lumber and sundries	500.00
Total first cost	$3,000.00
Less salvage, on sale of plant	1,800.00
Cost to be charged to this work	$1,200.00
$1,200 ÷ 23,400 = $0.0513, cost of plant per cu. yd. of earth moved.	
Labor cost per cu. yd.	$0.273
Plant cost per cu. yd.	0.0513
Total cost per cu. yd.	$0.3243
Ran 45 24-hr. days, Dec. 5, 1906, to Feb. 20, 1907.	

Hydraulicking a Dam with Mine Tailings. Cyril Wigmore is the author of an account in *Engineering Record*, Sept. 9, 1916, describing the work performed by an Arizona copper mine for the storage of mine tailings. Mill 6 of the Arizona Copper Company is situated near Morenci, at an elevation of 5,000 ft. The average production of tailings from this mill amounts to about 1,500 tons per day, and the disposition of this waste product has been the subject of careful study on the part of engineers retained by the company.

On account of the floods during the rainy season the main cañon was considered a difficult place to impound tailings. However, the first storage for tailings was provided by a dam constructed across the main cañon about 1,200 ft. in length and equipped with a timber wasteway and tunnel for the purpose of carrying

off the settled waters and the runoff from the drainage basin located above.

This dam was an earthfill built up with scrapers and provided with a hydraulic-fill core. The height was approximately 50 ft. and the basin back of it was completely filled with tailings, about 250,000 tons being impounded. The cost of placing the earthfill with teams and scrapers, however, was excessive and figured out to be approximately 6 ct. per ton of tailings impounded. It was, therefore, deemed necessary to devise some other, less expensive, scheme for disposing of the tailings.

After a series of experiments carried on in 1907 and 1908 a plan was devised for using the coarse sandy portion of the tailings to build up a hydraulic-fill dam, while the finer material was held back from the face of the dam itself for a considerable distance upstream. A site was selected in one of the branch cañons which would hold approximately 6,000,000 tons of solids when filled to the height which the low hill on both sides of the cañon fixed as a storage limit. In making this calculation, 1 ton of tailings deposited under water was taken as the equivalent of approximately 20 cu. ft. in volume.

At the site selected for the dam an 8-in. wood-stave pipe was laid along the axis of the cañon from a point below the downstream toe, extending upstream approximately 4,000 ft. At intervals of 300 or 400 ft. in this pipe tees were placed with a nipple, elbow and length of pipe standing vertically, the nipple fitting loosly in the tee so that the pipe could be swung in a vertical arc. By this means the entrance to the pipe could be kept at the reservoir level and would draw off only the clear surface water. At the lower end of this pipe line, below the toe of the dam, pumps were installed which returned the clear water to the mill to be used over again.

The surface of the ground at the dam site consisted of soil and detritus carried down from the mountains. Nothing was done to prepare the surface for the dam except to scrape up a dike about 6 ft. high along the downstream toe. This dike was to prevent tailings from washing away until the scheme of construction could be put into effect. The flume itself was set back about 20 ft. from this dike.

First Installation. The first installation at the dam site consisted of a 10 x 12-in. flume (Fig. 19) made of 2 x 12-in. plank supported on bents 12 ft. apart. The bents were constructed of 2 x 6-in. lumber with legs supported on small foot-boards and with 1 x 6-in. diagonal bracing. The flume was approximately 1,000 ft. in length and was built on a 2% grade, which made the center bent of the flume about 24 ft. in height.

In the bottom of the flume ¾-in. holes were bored ever 4 ft. and beneath these were fastened short troughs or spouts made of two pieces of 1 x 6-in. lumber 6 to 8 ft. in length. These spouts pointed down the cañon and were given a pitch from the horizontal of from 30 to 60°, which was varied as required. The coarse sands, being heavier than the finer material carried in suspension, traveled along the bottom of the flume and poured through the small holes in steady streams without permitting the escape of much water. This coarse material rapidly piled up beneath the spouts, and from these piles it was shoveled up by hand in a continuation of the dike which at first marked the downstream toe of the fill.

The percentage of coarse sand carried determined the number of small holes that would be kept open. In order to increase the height of the dam uniformly throughout its length, successive sections of the flume were used in rotation.

At first small pipes about 3 in. in diameter were placed through the earth dike to carry off the excess water and prevent the washing away of the material, but the hydraulic fill was found to build up very rapidly, and by keeping the dike a foot or two higher than the depositing material the fill was found to assume a grade of about 7% on the upstream side. This flat slope resulted from the incoming water and fine material impounded behind the coarse fill. It is notable that the water drained from the coarser material with great rapidity, and it was possible to walk over it almost immediately. In a few hours there was no water visible in the higher portions of the slope. It was observed that the fill settled very slightly on account of the solidity with which the material packed down as it fell from the flume. The filling of the cañon required the use of three dams, all of which were built in the same manner.

One laborer per 8-hr. shift was found to be enough to keep the dike shoveled up along the crest of the downstream slope. It was intended to keep the incline of this slope at about 30°, but it was found that the sand shoveled up by hand assumed a slope of about 45°, and this was allowed to govern. The fill was continued on each stage until the material reached the bottom of the flume and necessitated its removal to a new position. When the flume was moved it was set back upstream a sufficient distance to bring the general slope of the downstream face to about 30°, as shown in Fig. 19. In moving the flume, bents which could be easily pulled were taken out and used again, the others being abandoned. The loss of lumber was very slight.

Four men were normally required in the construction of the dam. One man on each of the three 8-hr. shifts watched the

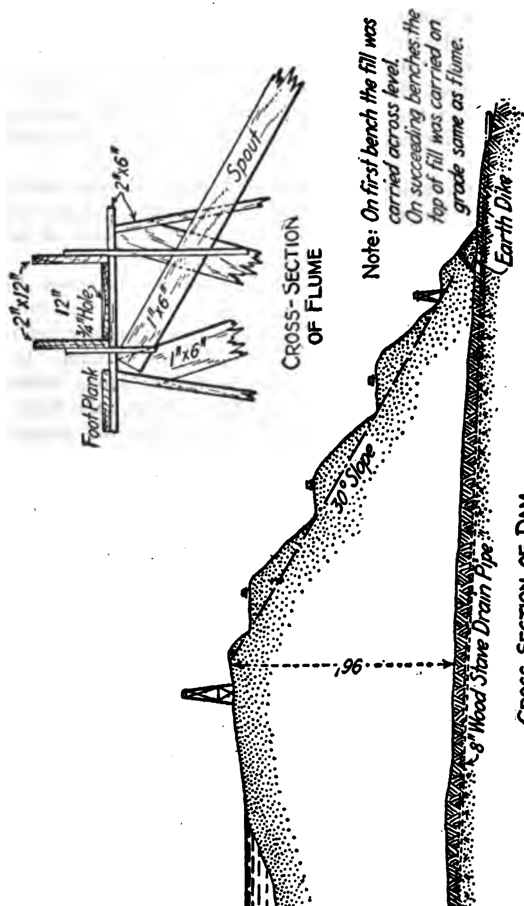


Fig. 19. Cross-Section of Dam and Flume, Latter Showing Discharge Hole and Spout.

flume, attended to the plugs in its bottom, and shoveled up the dike or border, while a fourth man acted as foreman. The moving of the flume necessitated by the completion of each stage in the building of the dam occurred at intervals of about 90 days. Flood waters were carried off through a tunnel driven through a hill on the west side of the basin. A 6 x 6-ft. timber waste tower was built at the entrance to this tunnel, and the height of this tower was increased from time to time as the work advanced.

The cost of handling the material used in constructing a dam 96 ft. high, amounted to approximately one cent per ton, not including the cost of the water, and about 1,500 tons of tailings were placed daily.

The Calaveras Dam. G. A. Elliot, in *Engineering Record*, Aug. 19, 1916, gives the following:

The Calaveras dam is the highest earthfill structure yet undertaken, and in volume is second only to the Gatun dam. It is 45 miles southeast of San Francisco. The height above bedrock at the center is 240 ft., the crest length 1,300 ft. and the base width 1,300 ft. The upstream face slope is 3:1 and the downstream 2½:1. It will contain 3,084,700 cu. yd., of which 1,300,000 cu. yd. are now in place. To prevent seepage under or around the structure, a trench 25 ft. wide and 8 ft. deep has been cut in the bedrock under the crest line. On the west side, due to the presence of seamy rock in the abutment, this trench has been carried 50 ft. below the ground surface.

Construction was begun in 1913 and will be completed in 1918.

Practically all of the hydraulic fill in the dam has been pumped. The location of only one of the eight borrowpits used was at an elevation sufficient to deliver the material by gravity. The distance of transportation has varied from 1,000 to 4,500 ft. The equipment used in the work consists of motor-driven centrifugal pumps.

At the present time two sluicing units are used. A three-stage 8-sec.-ft. centrifugal pump, direct-connected to a 500-hp., 2,200-volt induction motor running at 600 r.p.m. is mounted on a barge in the reservoir above the partly completed dam. The water is pumped through 12-in. slip-joint steel pipes, and is delivered at the pit with a nozzle pressure of 75 lb. Hendy giants, with discharge tips varying from 2½ to 4in. in diameter, are used on the end of the line. The size of the discharge tips varies with the material, depending upon the cutting force necessary to bring down the banks.

The second station is located in the cañon below the dam and receives its supply through a suction pipe laid through the out-

let culvert. This installation consists of two units, one with a capacity of 8 sec.-ft. against a 400-ft. head and one of 4 sec.-ft. against a 550-ft. head. The water from the smaller pump is delivered with a 75-lb. head and is used to cut the banks. Water from the second unit is delivered at the pit without head and simply gives a volume sufficient to carry the material to the dam. By dividing the pumping head in this way a considerable saving was effected in the power cost.

Handling of Jets. The jets are directed against the toe of the borrowpit bank, which is undermined, causing it to cave in. This results in the spoil being broken up and allows the water to carry it away. The soil-laden water flows to the lowest point in the pit, passing through a grizzly or screening device made of vertical 2-in. pipe set 4 in. apart. Rocks more than 4 in. in diameter are screened out and passed through a crusher set just below the grizzly. From this point the material is pumped by a 12-in. mud pump driven by a 300-hp. motor through a 14-in. slip-joint steel pipe to the toe of the dam.

The pipes discharge their contents on the outer edges of the toes. The flow is directed toward the center of the dam by the work of one man, who by the use of boards so controls the discharge from the pipe line as to build up small dikes along the edge of the toes. The coarser fill remains near the point of discharge, the remaining burden of the water being deposited automatically as the velocity of the stream decreases, until the pond is reached. Here the fine clay is settled in comparatively still water. The point of discharge is changed along the toes by the removal of successive pipe lengths, to maintain uniform relation between the widths of the dry banks and pond. Pipes are removed from the end of the discharge line without interruption to the pumps, so that a delivery run across the toe is always begun from the end furthest from the pit.

Operation of Mud Pumps. The mud pumps will operate against a head of 80 ft. When the head exceeds 80 ft. a booster of equal capacity is cut into the line. The head on the mud pumps depends largely on the character of the soil. With an excess of clay the friction is comparatively low, and the power required is a minimum. An example of this fact may be had with the present arrangement at Calaveras. In order to reduce interruptions to a minimum, duplicate units have been installed, so that should work be discontinued for any reason the crew can be immediately moved to another location. Two pits at the same elevation and the same distance from the dam are used alternately. One of these pits is composed of about 65% clay and 35% shale rock. In the other these percentages are re-

versed. When using the first pit one pump is sufficient. If the second pit is used, a booster has to be cut in and the power is doubled.

Wear of Pipes. One of the problems encountered in the work was to reduce the wear on pumps and pipes. The velocity of the water and the character of material which it carries are the factors that affect the life of the carriers. Although a high velocity is desirable to secure the maximum carrying power of the water, it was found that the minimum velocity in the pipe lines which would keep the material in suspension caused the least wear on the pipes, and although the output was decreased the resulting unit cost was lower. With the installation described this critical velocity was 12 ft. per second. On an average the water carries 8% of its volume of material.

All the wear takes place on the bottom third of the pipe circumference. This feature is so pronounced that the coating on the interior of the line is not disturbed on the top two-thirds of the circumference even when the plate at the bottom is worn through. High-carbon steel pipes are now being tried, and the result has justified the slight increase in initial cost. The pipes are turned twice during their life, allowing full use to be made of the metal.

Wear of Pump. The runners or impellers in the pumps are subject to excessive wear. A worn-out runner means an idle crew for half a shift while it is being replaced. Three kinds of material have been used — cast iron, cast steel and manganese steel. Manganese-steel runners cost about six times as much as cast iron; but the cost per cubic yard was cut almost in two by the use of the former. In some cases it was found that the manganese-steel runners wore unevenly, becoming unbalanced and creating excessive vibration of the pump.

The yardage handled through the life of a runner varies with the character of the material pumped. It has varied from 30,000 with sand and gravel to 200,000 with excessive clay and soft shale rock.

Removal of Water from Pond. During the first year of sluicing the excess water in the pond was allowed to flow out through a vertical pipe in the center leading to the culvert. To give this pipe stability a double line was used, consisting of a 16-in. pipe set inside of an 18-in. pipe, the space between the two being filled with cement grout. It was found that as the length of this pipe increased it was susceptible to the movement of the clay core, and this scheme was abandoned and the pipe filled with concrete.

Two trenches 4 ft. wide were cut through opposite ends of the upstream toe and bottomless flumes constructed of 1in. boards

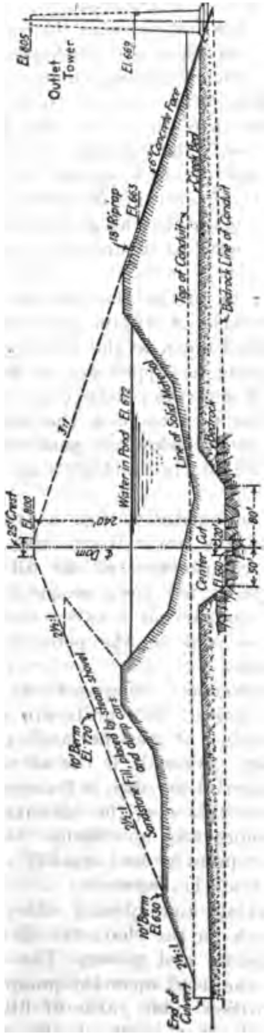


Fig. 20. Cross-Section of Calaveras Dam, Summer of 1916.

with 4 x 6-in. posts and 2 x 4-in. spreaders. Excess water from the pond is allowed to flow out through the box which is farthest from the point where the pipes are discharging, and runs down the slope of the dam, which is riprapped up to the outlet to prevent erosion of the slope. To raise the level of the pond, rock and gravel are dropped into the cut to the required height for the width of the dry toe. The amount of clay contained in the discharge from the pond varies from 0.1 to 2%. This depends on the relative amounts of material delivered, clay sometimes being wasted in order to maintain the proper relation between the dry toes and the clay core, to insure the stability of the structure.

Monthly tests are made of the clay core by taking samples of the fill at 10-ft. intervals. A 1½-in. pipe with a wooden plug in the lower end is forced down to the point at which the sample is to be taken. The plug is tapped out by means of a rod put down inside of the pipe, and the plastic clay presses into the end. It is impossible for four men to force the pipe any deeper than 60 ft. At a depth of 60 ft. below the pond surface a practically constant relation of 75% of clay and 25% of water by weight is found.

In addition to this quantitative test a traverse of the pond between the upper and the lower toe is also made, in order to ascertain the relative compactness of the fill. This traverse is made by forcing a pipe as far down as possible into the fill at 50-ft. intervals. The comparison between the periodical depths and distances from the edge of the pond is indicative of the consolidation of the mass.

Labor and Cost Conditions. Comparatively few men are employed on the sluicing units. Two units are working two shifts each and the total number of men per unit per shift is fifteen, making sixty altogether. When it is considered that an average of 3,600 cu. yd. of material per day is transported a distance of 3,000 ft. with a crew of this size, the advantage of this method of excavating and placing fills is evident. With the single exception of the relative quantity and quality of the fill, nothing is left to the judgment of the engineer.

The cost of excavating and placing this by the hydraulic method depends as much on the character of the material as on the cost of labor, material and power. The relative coarseness of the material affects the head upon the pumps. The direct cost of sluicing the first million cubic yards of fill was about 25 ct. per cu. yd. This is the bare cost of the work and includes only the expense of pipes, pumps, motors, belts, power and labor used directly on the sluicing work. No interest, overhead, super-

intendence, insurance or the prorated auxiliary costs of clearing the reservoir site, building and maintaining roads, trails, camp, etc., are included in this figure. In this connection it must be borne in mind that the work accomplished so far has been on the base of the dam, and that as the height is increased the unit cost of placing the sluiced fill will also increase.

The work is being carried on by G. A. Elliot, engineer of the Spring Valley Water Company.

Sliding of the Dam. Before this dam was finished, a large part of it slid out, as described in Chapter XX.

Percentage of Solids Carried on Calaveras Dam. According to *Engineering News*, Oct. 1, 1914, the material for the construction of Calaveras Dam, California, consisted of 20 to 50% of clay, and the remainder of gravel and sand. This was sluiced from a borrow pit, and down an open channel, having grades varying from 5% to 7%, to an 8 x 8-ft. concrete-lined sump. In the open channel near the sump, was a screen by which all boulders larger than 5 in. in diameter were removed. The consistency of the mixture arriving at the sump was usually about 20% solids and 80% water. At the sump this was automatically diluted when necessary, an average of about 15% material in suspension being carried to the dam.

Hydraulic Grading of Westover Terraces, Portland, Ore. R. M. Overstreet, in *Engineering Record*, Sept. 12, 1914, gives the following:

The work consisted in cutting down a steep hill and grading it into roads and terraces by means of hydraulic giants, sluices and sheer boards. A large part of the earth was carried half a mile in a flume and used for filling low ground. The total yardage was approximately 3,000,000.

Plant. The installation of pumping machinery at that time consisted of four 10-in. five-stage Worthington centrifugal pumps direct connected, in units of two each, to two 650-hp. two-phase, 60-cycle, 2,000-volt Westinghouse motors with a 25% continuous overload capacity. The guaranteed efficiency of the motors was 90% and of the pumps 70%, making a combined plant efficiency of 63%. The pumps were designed to deliver 8,400 gal. per min. under 375-ft. head at 690 r.p.m.

As the excavation progressed the pumping head continually increased so that it was necessary to install (Oct., 1910) additional pumps as follows: One 16-in. Worthington turbine pump, direct-connected to a 900-hp. Westinghouse two-phase induction motor. The efficiency guaranteed on the motor under full-load condition was 91%. The pump was designed to deliver 8,400 gal. per min. under a pumping head of 675 ft. with a head

on the suction of 375 ft. from the five-stage pumps, leaving a resultant head of 300 ft., and the efficiency guarantee was 71%, making 64.6% the efficiency of the combination.

After a shutdown of 14 months from Sept., 1912, to Nov., 1913, the pumping plant was entirely rearranged. One group of two 10-in. pumps with motors had been taken to another piece of work after the shutdown, which left but two 10-in. pumps at elevation 25, while the 16-in. pump was taken to a point on the hill west of the improvement and set at elevation 326 to act as a booster in the line. The discharge from the lower pumps was through two lines of 18-in. wood-stave pipe for 1,500 ft., and

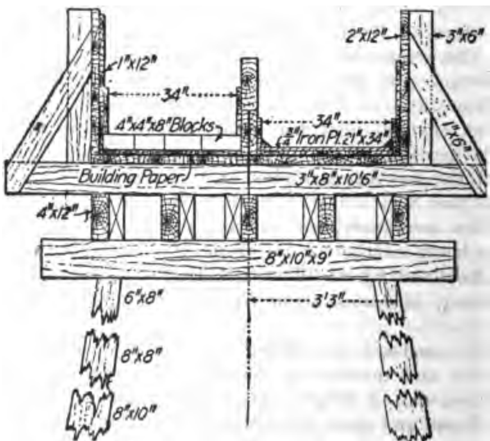


Fig. 21. Section of Flume.

from here in a 24-in. pipe to the booster. From the booster there were two 18-in. lines, 400 ft., converging into a 24-in. line, 300 ft. long, leading to a plug. From this point the 14-in. supply lines were taken off to the giants. Two giants were connected up, but only one was used at a time. A record of the elevation and location of the giants was kept and the pressure taken on each giant once every 8-hr. shift, and the discharge computed from these pressures. The working pressure at the nozzle varied from 50 to 80 lb., according to the elevation of the giant and size of the tip.

In 1914 the plant remained the same, there being a connected load of 1,550 hp. which delivered about 5,850,000 gal. of water per 24 hr. against a total head of 745 ft. with an efficiency of

about 49.3%. This low efficiency was due to the throttling of the booster pump which was operating under conditions far different than those for which it was designed.

Trestle and Flume. The earth was carried to the dump in the lake in a 6% grade flume supported on top of a timber trestle crossing streets and private property and having a maximum height of 75 ft. and a total length of 2,500 ft. See Fig. 21. A temporary flume on a 9% grade was bracketed to the side of the trestle and used for making a fill of about 300,000 cu. yd. about half way between the cut and the lake tract. The water lines from the pump house to the giants were also hung on this trestle. The 6% flume was divided into two channels by a bulkhead. One side of this was lined with 4 x 4 x 8-in. blocks laid with the grain up and the other side with ¾-in. white iron plates, 21 x 34 in. in dimension and weighing about 140 lb. each.

The cost of construction of the trestle and flume, not including the lining, was $24.20 per 1,000 ft. b. m., of which $9.08 was for labor, $2.12 for iron and nails, and $13 per 1,000 ft. b. m. for lumber. This is equivalent to $6.75 per lin. ft. Iron plates cost from 1¾ to 2¼ ct. per lb.

Life of Iron Plates and Wood Blocks. The life of the iron plates was very satisfactory as compared to the wood blocks. The average life of the wood blocks on a 6% grade, working in gravel, was found to be 125,000 to 150,000 cu. yd., while with the plates it was possible to carry 1,000,000 to 1,200,000 cu. yd. With the block lining it was found necessary to replace blocks about every five weeks, which would have occasioned considerable loss of time had it not been for the extra flume. It was found that the gravel running over the steel plates made so much noise that residents in the vicinity complained of being unable to sleep at night, so the steel-lined flume was used during daylight hours and the wood-lined side at night. Life of wood blocks in clay was found to be about 1,000,000 cu. yd.

Tunnel. At one point a flume was carried through the hill in a tunnel 5½ by 6 ft. in section. This tunnel was constructed on a 10% grade through hard gravel. It was about 530 ft. long and cost $2.95 per lin. ft. This tunnel was extended up through the property from the original portal by constructing a covered box and filling over it. In Sept., 1912, the 6% flume was torn down and all remaining material sluiced through the tunnel.

Sluicing. When running in gravel the discharge end of the flumes had to be cleared away every few days, as the gravel would pile up and not spread, so that it was necessary to level off the gravel fill with a steam shovel and cars. When running

in clay the material would flow 800 to 1,000 ft., making a fill as level as a table.

Blasting Clay. When the giants were working in gravel the bank was undermined by pressure from a jet without the use of powder. In clay the pressure of the stream had little effect on the bank and it was necessary to blast the material. A powder crew, consisting of 8 men, was employed on the day shift to keep the clay broken up in front of the giant. By al-

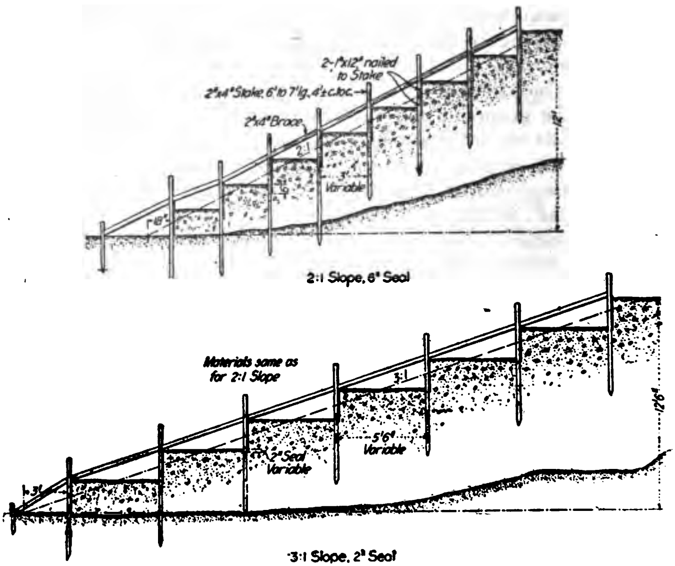


Fig. 22. Arrangement of Sheerboards for Slopes Made by Hydraulic Sluicing.

ternating giants from one shift to another it was possible to keep the clay well broken up for a full day's run. A stumping powder of 20% strength was used in charges of from three to seven sticks, and from 400 to 700 lb. were used daily. Powder cost $176 per ton delivered on the work; fuse, $4.50 per 1,000 ft.; and caps, $9.80 per thousand.

Terraces Built with Sheerboards. The hill attacked in this work was graded into a series of terraces and streets, sheerboards being used to hold the material to the desired slope. See Fig. 22. These were made up of two 1 x 12-in. pieces nailed

one above the other to 2 x 4-in. stakes, 6 or 7 ft. long, spaced about 4 ft. center to center, and driven into the ground in the embankment. The first row of sheerboards is placed at the line of intersection of the slope with the ground; the second, third and subsequent rows of sheerboards are placed as the embankment rises, each line being spaced according to the designed slope. Slopes on this work were 1½ to 1. The bottom of each sheerboard is placed from 2 to 10 in. below the top of the upper board in the preceding bulkhead, depending on the nature of the material of which the embankment is being made. In gravel, for instance, the seal is less than is required for making a fill of fine clay. In the lighter and finer soils it is necessary to brace between the stakes as shown. After depositing its load the water is taken off the fill through spillways, which are located at convenient points. These consist merely of flumes running down the slope through the sheerboards. By this method the mass of the embankment is continually drained as the fill is deposited, and when the fill is completed it is as compact and substantial as though it were in the original bank. The amount of lumber required for the sheerboards can be obtained from the following data:

Depth of seal, in.	Feet, board measure
2	1.09 x area of vertical projection of slope
4	1.20 x area of vertical projection of slope
6	1.33 x area of vertical projection of slope
8	1.50 x area of vertical projection of slope
10	1.71 x area of vertical projection of slope
12	2.00 x area of vertical projection of slope
Stakes and bracing	1.50 x area of vertical projection of slope

Add 10% for loss due to lap, waste, etc., on 1 x 12-in. lumber.

When pumping against a head of 420 ft. during July, 1910, with 1,300 hp. connected, the yardage moved was 37,800 cu. yd., requiring 130,000,000 gal., the earth carried being 5.78% of the volume of water in flumes of 6% grade. The cost of pumping per million gallons of water was:

Electric current at 0.6 ct. per kw.-hr.	$24.38
Pump, operators, $270 for the month	2.08
Supplies, repairs, etc.	0.48
Total per million gallons	**$26.94**

There were 245 gal. pumped per kw. hr. The pumps worked 539 hr. during July. In February, 1914, the average pumping head was 707 ft., and 101,790,000 gal. were pumped, moving 94,691 cu. yd. the ratio of earth to water being 18.6%, which was the highest percentage attained; the grade of the flumes being 10%. The cost of pumping per million gallons was:

Power at 0.6 ct. per kw.-hr.	\$29.68
Pump operators, including booster pumps, \$515	5.05
Supplies, repairs, etc.	0.57
Total per million gallons	\$35.30

The connected horsepower was 1,550, and 434 hr. were run during the month. The material was clay. The work was carried on for 34 months at an average rate of 75,000 cu. yd. per mo., and the article above quoted contains a table giving output and pumping cost data for each month of the entire period. The price of electric power was very low (0.6 ct. per kw. hr.), and about 9.3 kw. hr. were used per cu. yd. of earth, the earth being mostly clay, and the average pumping head about 600 ft. Each cubic yard of earth required an average of 2,100 gal. Hence the power for pumping (at 0.6 ct. per kw. hr.) cost about 5.6 ct. per cu. yd., or \$27 per million gallons. About 226 gal. were pumped per kw. hr.

A typical distribution of the pumping heads was as follows, on Apr. 16, 1914:

Loss of head in pumps	18.4
Loss in pipe lines to booster pump	12.0
Loss in booster pump	34.5
Loss in pipe line to giant	30.2
Effective head at nozzle	109.2
Lift to nozzle	556.6
Total pumping head, ft.	770.9

Disposal of Earth by Means of a Chute. *Engineering and Contracting*, Oct. 13, 1909, gives the following:

In the construction of the new engine house at the Lake View pumping station at Chicago, Ill., the contractors used an economical and efficient method of disposing of the sand and gravel encountered in the excavation for the foundations of the building.

The building is located about 300 ft. from the shore of Lake Michigan and the sand and gravel were conveyed by a chute to the water's edge of the lake, where the waves disposed of it after each storm. A pump installed for taking care of seepage water was used to wash the sand and gravel through the chute. Some trouble was first experienced, owing to the fact that the fall was not great enough. It was found that to handle the sand by this method it was necessary to have a grade of about 5%. One or two men were placed along the chute to prevent accumulations of sand, for if it started to collect, it would accumulate very rapidly and cause a blockade.

When it was found that the chute would be a success, a screen of ¼-in. mesh was placed in a section at the bottom of the

chute for a distance of about 8 ft. in length. The sand going through the screen was allowed to fall into another portion of the chute at a lower level, the gravel accumulating on the screen being removed by one laborer with a hose. In order to remove the large gravel and cobble stones the gravel was allowed to fall over another screen of 1¾-in. mesh. Between 50 and 60 cu. yd. of the best quality of gravel for concrete was obtained in this way each day at the cost of four laborers' wages. After the gravel screen had been in successful operation, another screen was placed in the chute lower down; this screen had 10 meshes to the inch. From this screen about 20 cu. yd.

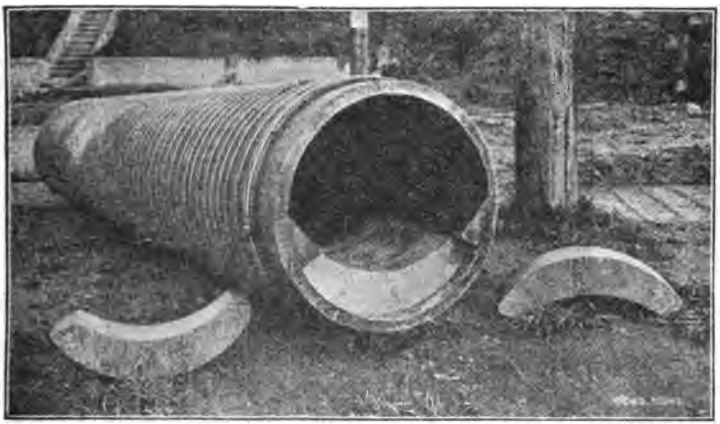


Fig. 23. Wood Blocks and Retaining Ribs Before Use.

of the best quality of torpedo sand and gravel was obtained each day, at the cost of one laborer's wage. In all there was obtained about 2,000 cu. yd. of torpedo sand and gravel suitable for concrete. About 12,000 cu. yd. of sand and gravel were handled by means of the chute.

The Denny Hill Regrade, Seattle. This project, comprising an area of 43 city blocks, was undertaken at Seattle, Wash., as described at length in *Engineering News*, Mar. 31, 1910; 5,400,000 cu. yd. of material were moved from a section in the heart of the city by the hydraulic method. The maximum length of cut was about 3,000 ft. and the maximum depth 110 ft. The contract price was 27 ct. per cu. yd. The material was discharged into deep water in the harbor. In order to avoid dis-

turbing street traffic it was carried part of the way through a tunnel under the street.

Besides the hydraulic jets, which were steadily eating into the breasts of the various cuts, a construction railway had been constantly in operation, hauling dirt from the steam-shovels and dumping it into an open cut. Two trains, consisting of four side-dump cars each, were operated on this single-track road, with a third locomotive to help out on the steeper grades.

In order to break up the dirt from these trains and wash it into the tunnel, two small-size giants were installed at this point.

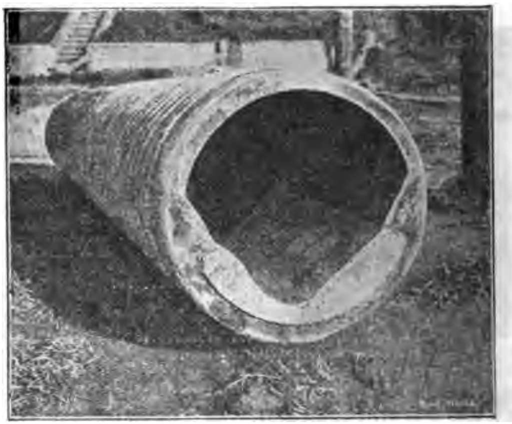


Fig. 24. Effect of Wear on Blocks.

These were supplied by a 2-in. and a 4-in. iron pipe, respectively.

One feature of the work which was favorable to its early completion was the small percentage of rock occurring in the mass to be removed. And although the greater part of the mass was a very hard, blue-black clay — so hard and closely-compacted, in fact, that in the earlier attempts it was seriously doubted that it could be handled hydraulically at all — still the hardest part of the work is now past. And at this time, the close of 1909, the entire project is more than three-fourths completed.

Sluiceway Linings. An interesting point in connection with all hydraulic grading is the extreme difficulty encountered of finding any substance which will resist the high attrition in the sluiceways. The remedy finally hit upon was removable wood blocks, placed end up. Where these are used in wood-stave pipe,

two of the side-sections of same are cut larger to act as retaining ribs (see Figs. 23 and 24) and the blocks are turned in a lathe so as to give a maximum length of block at the bottom of the pipe, or point of greatest wear. So important is this point, that the use of wood-block lining has been patented by a local firm, and one successful damage-suit has already been brought against infringers.

Where the wood-block lining is used in flumes, tunnels, etc., oblong blocks, 6 in. long, are cut from 6 x 12-in. rough lumber, and the bottom of the sluiceway is lined with these, laid end up to wear. Evidently, when these wear out, it is a simple matter to remove them and replace with new blocks.

In order to hasten the sluicing, both by the loosening of large masses and by the breaking up of the more closely-compacted lumps of the shale-like clay, blasting powder is used throughout the area under regrade. Comparatively small charges are used, however, and very little disturbance has so far resulted from this cause.

Sluicing Silt to Reduce Canal Leakage. The following is from an article by Fred J. Barnes in *Engineering News-Record,* May 17, 1917. Leakage from the main canal of the Grand Valley irrigation project in Colorado became excessive and an attempt was made to stop it by sluicing clay, in the hope that the clay would settle into the porous material in which the canal was built and stop the leakage.

At one point there was a small bed of about 8,000 cu. yd. of clay. This material was very dense and compact, in its natural state requiring a pick to loosen it. It contained 16% moisture and very little sand. The sieve test indicated 100% passing a No. 50 screen, 99.85% passing a No. 100 screen, and 98.22% passing a No. 200 screen. The bed was on the upper side of the canal immediately adjacent to and above the water surface of the canal.

A two-stage centrifugal pump with 8-in. suction and 6-in. discharge was direct connected to a 75-hp., 890 r.p.m. induction motor mounted on the pump base. A suction sump was built in the canal, and the motor and pump were installed in a small shed adjacent. The discharge line consisted of 40 ft. of 8-in. spiral-riveted iron pipe and 75 ft. of heavy 6-in. canvas hose connected by a flange union to the giant. The latter was mounted on a heavy frame to hold it in position and had counter-weights to facilitate handling the nozzle. The giant proper was about 6 ft. long, tapering in inside diameter from 7 in. to 3½ in. An additional nozzle of 3-in. inside diameter was also provided.

A cut was made through the upper bank of the canal to drain the effluent from the clay pit into the canal. A 2-ft. metal Ap-

poletti weir was installed in the cut. A wooden flume extended from the weir across the canal, clearing the water surface by 6 in. Notches of varying depths were sawed in the vertical sides of the flume at 2-ft. intervals to distribute the muddy water evenly over the channel flow.

The pump discharge was found to be 3.1 cu. ft. per sec. With the 3-in. nozzle this gave 63.8 ft. per sec. issuing velocity. By elevating the giant the stream could be thrown about 150 ft. horizontally. With the 3½-in. nozzle the issuing velocity was 46.7 ft. per sec., and the extreme horizontal range was about 110 ft. One man attended to the motor, pump, pipe line and distributing flume, while a second man handled the giant.

The idea was to utilize the maximum force of the stream in breaking down the clay to small particles and getting it thoroughly mixed with the water. It was found most advantageous first to dig a deep hole in one side of the clay bank by holding the giant pointed downward on a small area for 15 min. or so. The sides of the clay bank were then trimmed to a vertical face, and the giant stream was played over this face. It appeared best to keep the stream moving continually over the face of the deposit, so as to remove the material in thin layers rather than to undercut large masses and have them fall into the sump. The clay required considerable agitation before becoming thoroughly mixed.

The crest of the weir in the cut from the sump to the distributing flume was about 2 ft. above the bottom of the sump, so that this served as a settling basin for larger lumps. The sump floor was kept at this elevation by occasionally turning the giant stream downward and keeping it pointed on one place for a short period. After the clay became thoroughly saturated, it mixed with the water readily and remained in suspension for about 60 min. in still water, although some precipitation began immediately.

The effluent passed the weir with a vertical fall of 2 ft. and was carried out in the wooden flume with a velocity of about 5 ft. per sec. over wooden riffles on the bottom, which tended to grind up still more any pieces of clay that had been swept along. Samples of effluent were taken at 2-hour intervals to determine the percentage of clay carried in suspension. These samples varied widely, showing from 4 to 5% of clay by weight; the average clay content, as indicated by samples, was 5.4%. The total running time was 83½ hr., during which period 941,000 cu. ft. of water left the giant. The total amount of clay moved out, determined from cross-sections of the bank before and after

sluicing, was 2,749 cu. yd. This indicates 7.88%, by volume, of clay in the water.

The effluent after entering the canal passed through different types of section where, on account of the rapid succession of abrupt changes in velocities, the rapidity with which the silt dropped could not be accurately found. It was observed that there was little tendency toward separation when the velocity exceeded 1 ft. per sec.; but when the mean velocity dropped abruptly from 1 ft. per sec., or more, to 0.4 or 0.5, there was immediate precipitation. Only slight quantities of silt were carried as far as Lewis siphon; the bulk dropped out in the first 2 miles below the tunnel.

The largest observed percentage by weight of silt in the canal water immediately below the silting plant (and due entirely to the plant operation) was 0.48%. At Lewis siphon the largest observed content was 0.002%, indicating practically complete precipitation in 8.8 miles — neglecting the 1.4 miles of tunnel where precipitation was impossible.

The obvious conclusion is that for best distribution the velocity of the current in the canal should exceed 1 ft. per sec., except where it is desired to deposit the silt.

The pressure head was found by gage, but no vacuum gage was available, so that the suction head had to be computed. The total head thus found was 135.2 ft., using a 3½-in. nozzle. The theoretical horsepower required was 48.3; the actual power consumed was 60 kw. at the Cameo power station, giving a combined efficiency for the transmission line, motor and pump of 60%. Using a 3-in. nozzle, the total head worked against was 160.7 ft. This required 57.3 hp. theoretically, and the actual consumption was 72.3 kw., making the combined efficiency then 59.2%.

When working the stream against a vertical face of the bank from a distance of 40 ft. or less, the 3½-in. stream seemed as effective as the 3-in., with much less power consumption. At greater distances or when digging was required, the 3-in. stream worked faster.

The installation cost of the silting plant was largely in repairs to the pump (an old one in poor condition) and labor of erecting the pump, motor house, pipe line, distribution flume, etc. All material was old stuff lying around the camp. The transmission line was already built. No depreciation charge was allowed on machinery, since much overhauling was necessary and the pump was in better condition after sluicing ended. The cost of power was comparatively high, 3.47 ct. per kw. hr. in September and 3.84 ct. in October (because of the small power

output for these two months at the station and the relatively high influence of fixed charges). The following was the cost:

Plant erection, labor	$0.066
Plant erection, materials	.001
Plant operation, labor	.039
Plant operation, materials	.001
Plant demolition, labor	.037
Power	.068
Engineering	.056
Closing entries (automobile expense, etc.)	.023
Total per cu. yd.	$0.291

Total clay moved, cu. yd.	2,749.0
Total power used, kw.-hr.	5,290.0
Power used, kw.-hr. per cu. yd. of clay	1.92
Hours of plant operation	83.5
Water pumped, sec.-ft.	3.129
Clay in suspension, %	7.88
Total head on pump using 3½-in. nozzle, ft.	135.2
Total head on pump using 3-in. nozzle, ft.	160.7
Approximate combined efficiency of transmission line, motor and pump, %	60.0

One item of $145.66 for giant, pipe and fittings, all of which were in as good condition after work was completed as when received, is not included in the above cost.

Bibliography. "A Practical Treatise on Hydraulic Mining in California," Aug. J. Bowie; "Manual of Hydraulic Mining," T. F. VanWagener; "Hydraulic and Placer Mining," Third Edition, Eugene B. Wilson; "Reservoirs for Irrigation, Water Power and Domestic Water Supply," James D. Schuyler.

"Hydraulic Excavation," Latham Anderson, *Jour. Asso. Eng. Soc.*, Vol. 26, Jan., 1901.

"Notes on Hydraulic Sluicing," *Eng. and Min. Jour.*, April 8, 1911; "Making a Fill by Sluicing Through a Flume," *Eng. News*, Jan. 22, 1914.

CHAPTER XIX

ROAD AND RAILROAD EMBANKMENTS

Although much of the information in preceding chapters is applicable to the building of embankments for roads and railroads, it is desirable to have a special chapter for this branch of earthwork.

Embankments for roads and railroads differ from other embankments, except levees, in that they are usually quite long. They differ from earth dams and levees in that they need not be watertight.

Road embankments are usually not so high as railroad "fills," and most of the earth is commonly secured from the ditches. The shallowness of the fills makes road work more expensive than railway work. Also the area of trimming of earth surfaces is proportionately greater for roads than for railroads, and makes the cost per cubic yard higher. Finally, it is usually specified that highway fills and subgrades must be sprinkled and rolled, whereas railway fills are seldom rolled or even watered to effect consolidation.

Contractors experienced in railway earthwork usually underestimate the cost of highway work, for the reasons just given. But study of the data in Chapter VI will prevent such underestimates.

It should also be remembered that the hard earth crust of an old road is often as difficult to loosen as hardpan, and that when loosened it is not as easily shoveled or scraped as ordinary field earth.

In designing railway earthwork, the engineer usually aims to "balance the cuts and fills," that is the earth yardage of the excavated parts of the railway line is made approximately equal to the yardage of the embankments. This frequently results in long hauls for the earth. Where the yardage is small and the hauls become very long, it is usually cheaper to secure the earth from "borrow pits" near the fills. The increasing use of dragline excavators will probably result in more frequent "borrowing" of earth for fills and "wasting" of earth from cuts, as described later in this chapter.

The shrinkage of earth embankments is discussed in Chapter I.

Besides shrinking, embankments are apt to settle into the material on which they are built, making it difficult to distinguish between settlement and shrinkage. A striking illustration of the settlement of an embankment is shown in Fig. 1, a diagram of what happened to a fill across the Papio Valley for the Union Pacific Ry.

A Method of Determining Subsidence and Shrinkage has been worked out for use on levees in the Orleans Levee District in Louisiana, and is described in *Engineering and Contracting*, Oct. 18, 1916. Briefly, a 2-in. pipe is driven until sufficient penetration is secured through good solid earth, so that the pipe cannot be disturbed by the superimposed weight. A 3-in. pipe screwed into an 8-in. flange, which in turn is bolted onto boards, is slipped over the 2-in. pipe. The boards give sufficient bear-

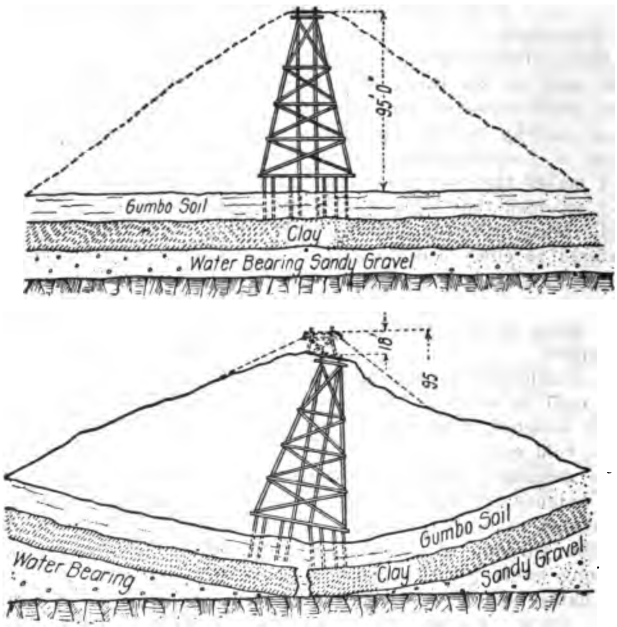


Fig. 1. Section Through 95-Ft. Fill Showing Subsoil Strata Before and After Settlement.

ing surface so that the 3-in. pipe sinks with the original ground. Its upper end is closed with a cap. Levels taken on this cap show the subsidence, and taken in connection with levels on top of the embankment they show the shrinkage.

Calculating the Ultimate Subsidence of an Embankment. In the *Transactions of the Association of Engineering Societies*, July, 1892, there is a paper by Henry M. Carter of the Boston Society of Civil Engineers, on the settlement of the embank-

ment between Squantum and Moon Island, Boston Main Drainage Works. The embankment is 4,200 ft. long built on soft material. The embankment was to be 20 ft. wide on top and to have side slopes of 2 to 1.

The original surface on which the embankment was to be built consisted of a gravel bar at about half tide elevation, varying in thickness from 2 to 8 ft., and extending from Moon Island 2,800 ft., toward Squantum. At this point the bar disappeared and the surface showed mud alone at the elevation of low water.

Two sets of borings showed an apparently solid gravel bar, so a contract was let for building an embankment on this bar and for dredging out the mud for the remaining distance and filling in with solid earth. After work was commenced a doubt was raised as to the extent of the gravel bar, and further borings showed it to be entirely underlain by mud. This discovery caused the abandonment of the original plans. It was decided to build the embankment to 2 ft. above the proposed grade and to allow it to settle thoroughly before attempting further work. A very careful set of borings was then made to determine the depth of mud along the whole line of embankment. Iron plates 2 ft. square, attached to rods, were set in the fill already built, so that records could be kept as these settled with the embankment.

Observations have been made on the settlement of this embankment for a period of 9 years. One rod settled 14 ft. during the first six months, 2 ft. during the next year, the embankment being built as the sinking took place. The entire settlement to date was 17.4 ft., the gravel filling having sunk through the mud until it rested on the hard clay beneath.

The settlement from 1885 on was plotted as a curve, and from these curves the ultimate settlement at each point was figured, as also the date when it would become less than 0.01 ft. per year. These calculations were used in setting the invert grade of the sewer. Rods were placed on top of the sewer with the intention of further study comparing the actual settlement with the calculated settlement.

A remarkable feature in the settlement of this embankment is that, while at points the fill has sunk through the mud until it is supported on the clay beneath, at other points it is still supported upon the mud. A fourth set of core borings show the condition existing when the embankment had settled to approximately its permanent position. A profile published with this paper gives a good idea of the degree to which the mud has been compressed.

A Tamping Roller. *Engineering and Contracting*, Dec. 4, 1907, gives the following:

The face of each roller is studded with numerous "iron feet" which do the tamping. See Fig. 2. In road or street work, the subgrade to be compacted is first loosened with a plow to a depth of about 6 in. When the rolling tamper is drawn over this loosened earth, its iron feet sink into it nearly to their full length, and thus begin the process of compacting the earth *at the bottom.* Successive trips of the roller over the earth result finally in a mass so thoroughly compacted that the "iron feet" no longer sink into it, but ride on top.

To test out the roller, a clay soil, weighing 90 lb. per cu. ft.

Fig. 2. Traction Engine Drawing Tamping Rollers.

in its natural state in place, was plowed up and rolled with rolling tampers until their "feet" walked on top of the compacted surface. Then a cubical block of this soil 2 ft. square and 6 in. thick was dug up and weighed. Its weight was found to be 115 lb. per cu. ft., as compared with 90 lb. before rolling. By mixing some gravel with the plowed clay, and rolling, a weight of 125 lb. per cu. ft. was easily secured.

The tamping roller is made by W. A. Gillette, South Pasadena, Calif.

Cost of Grading Southern Roads. The cost of grading a number of gravel and sand-clay roads in several of the Southern States during 1910, under the supervision of the U. S. Office of Public Roads, is given in a text book on Highway Engineering, by Messrs. A. H. Blanchard and H. P. Browne. The costs were as follows:

Soil	Cu. yd. moved	Cost per cu. yd.	Haul in ft.	Tools used	Labor 10-hr. day	Team 10-hr. day
Sand top, clay subsoil	2,400	15	200	Picks, plows, drag and wheel scrapers	$1.50	$2.00

Sandy	**3,635**	**11.2**	**223**		**1.80a**	**3.60a**
Subsoil, sand, loam, clay and mixture	**3,352**	**8.8**	**200**	**Road graders, 9 wheel scrapers, 8 drag scrapers..**	**1.60b**	**2.80b**
Sand and clay..	**3,654**	**6.06**	...	**Road machine, drag-scraper, 5 dump wagons..**	**0.50c**	**1.00**
Black waxy prairie subsoil	**6,407**	**38.1**	...	**Plows, graders ....**	**1.50**	**3.00**

a — 9-hr. day. b — 8-hr. day. c — convicts, mule team.

Road Work with Power Machinery. *Engineering and Contracting*, May 15, 1918, describes some very low cost work done on a road leading north toward Pontiac, Ill.

The first 5 miles of this highway was changed from a narrow winding road to a level, well drained all the year road, 60 ft. wide between fences and 40 ft. wide between drainage ditches.

Clearing. The work of clearing the right-of-way was started on May 1, 1917, and completed June 16, 1917, during which period 5.18 acres were cleared of a tangled mass of brush and shrubs and over 200 live trees from 3 in. to 3 ft. in diameter. Trees were pulled by a 75-hp. caterpillar tractor using a 100-ft. cable. Two cable outfits were used, so that the tractor was not delayed waiting for hitches to be made. The cost of clearing the roadway, including labor, interest on investment and an allowance of 20% for depreciation of equipment, was $990.90, or $191.29 per acre.

Grading. The grading was started on June 18, 1917. One 75-hp. caterpillar tractor was used to pull two Western graders, one 12-ft. to make the cut, followed by an 8-ft. to carry the dirt to the center of the road. A Western elevating grader pulled by a 75-hp. caterpillar tractor was used in some places in making fills. However, on some of the deeper fills it was necessary to use some other method, in order to make time, and a 75-hp. caterpillar tractor was used in connection with a caterpillar land leveler. This land leveler is a tool used extensively in the West and is in reality a large scraper having a capacity of approximately 3½ yd. With this machine the dirt could be taken up and carried across the road and then unloaded gradually or at one time, as conditions required.

The gravel for the surfacing of the road was taken from a nearby creek with a dragline excavator which delivered it to a loading hopper. With the dragline excavator working steadily it was possible to keep the hopper filled, so that when the tractor trains came up, which consisted of one 75-hp. caterpillar tractor and six reversible trailers, they could be loaded without delay or without shoveling.

With this equipment a total of a little over 125,000 cu. yd. of dirt was moved in 75 working days. The total cost, including labor, interest on investment and an allowance of 20% covering depreciation on equipment, was $5,147, or 4.1 ct. per cubic yard. At no time were more than 8 men, including the superintendent, employed on the job. Horses or mules were not used at any time in the work.

Road Embankments Over Marshy Ground. Highway embankments must often be built over soft ground where an indefinite amount of filling material sinks out of sight. It is difficult to build such embankments in layers because the ground is too soft to sustain horses or machinery. Many ingenious methods of overcoming the difficulties encountered have been devised, a few of which are described in the following paragraphs given in *Engineering and Contracting*, June 30, 1909.

In general some of the methods employed in securing a good foundation for roads over soft ground are as follows:

1. By draining the subsoil so as to consolidate the ground as much as possible.

2. Where the soft material is not too deep nor its extent too great, a trench may be dug and filled with solid material to form a foundation for the embankment.

3. By consolidating the soft material by driving short piles and throwing stone in the side ditches to prevent the muck from oozing to the sides. By filling in with stone or gravel and sand until an embankment is formed resting on the solid ground, and with its top rising to the required elevation.

4. By distributing the weight over the soft ground by means of brush mattresses, timbers, poles, etc.

By Draining. In most cases the firmness of the natural ground can be increased by digging wide and deep side drains parallel to the side of the intended road. In the case of bogs it is possible by draining the moss to condense it into a more or less solid peat. The undrained moss of bogs usually consists of about 10% of vegetable matter, the remainder being water. So it is necessary that the drainage be at a gradual rate to avoid carrying off particles of vegetable matter, thus causing the sides of the ditches to cave. The side drains are usually carried down into the solid ground, and it is well to cut them in a series of benches so as to expose as large a surface as possible to the sun and wind. The side ditches are placed about 30 ft. or more from the center line of the road, the distance depending upon the width of the berm which is to be left between the edge of the roadway and the side ditch. In no case should the berm be less than 6 ft., and it is better to have

it more than this if possible. Side ditching destroys the natural sustaining power of the bog, and the drains should therefore be made a considerable distance from the line of the proposed road. Cross drains cut at right angles to the side drains are placed at frequent intervals, in most cases about 30 ft. apart. These cross drains should extend across the site of the intended road and beyond the side drains from 50 to 100 ft.

By Consolidating the Soft Material. This was done in one case as follows: A country road supervisor was told to construct a corduroy road across swampy ground. Instead he took the logs and drove them endwise beside the road. These logs kept the muck from oozing to the sides and the road proved very satisfactory. The logs were about 16 ft. long and were put down with a hand pile driver made of an elm butt, with three handles so that three men could be used on it. In another case a country road superintendent drew cobblestones in the winter time and threw them into the ditch alongside the road. In the spring the stones sank out of sight. The next winter he threw in more stones. These stones sank some but not out of sight, and as a result he had two walls on each side of his road so that the muck could not ooze to the sides. There has been no sinking of this road since.

Filling in with Solid Material. This method is often employed in the case of sink holes and for soft places of no great length or depth. In one instance a sink hole about 60 ft. long was filled in the following manner: A crossway above the water level was first constructed of 3-ft. second growth ash poles. On this cobblestones were placed to a depth of 2 ft. and flanked by boulders to hold the dirt. The stone was then covered with gravel to the level of the road on each side of the sink hole.

Distributing the Weight Over the Soft Ground. Various methods have been employed for "floating" a roadway or railway embankment over soft ground. In one instance a railroad grade that has stood up for over 12 years without any trouble was built over ground so soft that a pole could be run down 30 ft. by hand, by first making a mat of trees and then placing earth on top of the mat. The trees were from 1½ in. to 3 in. in diameter.

In another case, a temporary road across a marsh of soft mud covered with high grass was built in the following manner: Drift wood was placed along the line of the proposed road, the bottom layer of sticks being placed lengthwise and the top layer crosswise. The high marsh grass was then cut and spread over the timber and covered with earth.

Somewhat similar methods were used in the construction of a

permanent road through a marsh. The marsh was about one mile, and was covered with water from a few inches to 2 ft. deep. The marsh was covered with wild rice about 8 ft. high, with stalks from ¼ in. to ⅛ in. in diameter at the bottom. Through the central portion there was an open channel about 10 ft. wide, which widened out into small pools every few hundred feet. The channel and pools had from 3 to 4 ft. of water and about the same depth of decayed vegetable matter. The turf was about 1 ft. thick with from 2 to 6 ft. of soft black vegetable mould underneath, beneath which was a hard bottom of blue clay. Beginning at dry ground, an 18-ft. x 1-ft. x 1-in. board was laid lengthwise on the outside, 9 ft. from the center of the proposed road. Another board was laid in the center 6 ft. in advance of the first board and a third board laid on the opposite side 6 ft. in advance of the second board. The three longitudinal pieces were covered with 18-ft. inch boards laid crosswise and nailed as fast as laid to keep them in their places. Three more boards were placed lengthwise on these, one each side and one in the center, and nailed through into the boards underneath. Wild rice for a space of about 75 ft. on each side was cut down and forked onto this "floating" platform, making a compact covering about 2 ft. thick. A turn around for teams was made at the end of the first 500 ft. of road. The first 500 ft. of roadbed was then covered to a width of 16 ft. with about 15 in. of stones, and on this was placed 3 in. of crushed stone. The road was built in 500-ft. sections, the turn around, which was made 36 ft. square of doubled boards, being moved to the end of each section. A pond about 200 ft. wide near the middle of the marsh was crossed by a bent bridge 50 ft. wide and by platforms the same as those used on the marsh, except wider. The road did not break through the turf in any place and only settled an average of 2 ft. This road was in service for over 25 years.

In one instance a wagon road was constructed over a bog by placing a layer of brush forming a mattress. On top of this mattress was placed material taken from the side ditches, and on top of this was placed a layer of larger stone, the whole being surfaced with 5 in. of gravel. In this case the surface of the bog was drained, care being taken to place the drainage ditches so that they would not impair the sustaining power of the natural crust of the bog.

In another case a road was constructed over a soft, deep, wet and yielding swamp on a raft constructed of long poles. Long poles laid longitudinally with broken joints formed the bottom course, and a second course was formed by poles laid transversely. The two courses were then covered with brush, and on

this was laid the earth and surfacing materials. The grade line was kept low and the filling was a clay loam. The black vegetable mould from the swamp should not be used for the earth covering. It is better to use clay loam, a gravelly loam, or clay. Sand when slightly moist makes a good foundation material. In some of these roads there has been remarkably little settlement. In the case of one road there was a settlement only of 2 in. after the roadbed had been subjected to heavy traffic for over a year. This embankment was built from peat bog at the elevation of mean high tide, but too soft to sustain a man without sinking in nearly to the knees. The road was 20 ft. wide with a 40-ft. carriageway and the grade line was an incline varying from 4 to 20 ft. above the surface of the marsh. The depth to the hard bottom was 8 ft. below the bog surface.

Dry peat was used by George Stephenson to carry the Liverpool & Manchester Ry. across Chat Moss in Great Britain. On the dry peat embankment was placed two layers of bundles to carry the ballast.

One of the first railroads constructed in New York state was carried across a swamp by spreading the pressure over a large surface by means of a wooden platform.

In the construction of a short piece of railroad over floating land it was not possible to put in a trestle because the ground was not strong enough to hold the piling. Accordingly small willow brush, which abounded along the right of way, was cut and bound into mattresses, which were spread in a uniform binding plan across the right of way. Stringers to support the ties were then laid parallel to the line of the road. Dump cars were next pushed out on this road and sufficient dirt was brought up and spread to allow of flat cars being pushed out on the track with an engine. The fill made in this way had a 2 to 1 slope, and in the main the plan was successful, although in some places the roadbed failed to hold.

In Cape May County, New Jersey, a number of roads have been constructed across marsh lands to connect seashore resorts with the main land. These marsh lands consist of large deposits of soft mud, in many cases 25 ft. deep, overlain by a sod or crust of sedge or grass roots. In many cases this crust is not of sufficient strength to support the weight of a horse. The methods employed in constructing these roads were as follows: A foundation is laid of poles and stringers of sufficient area to support the weight of filling soil and pavement, together with the added weight of travel, without breaking down the meadow crust. The sides of the roadway are protected from wash by curbing and bulkheading on both sides of the road throughout

the entire length, and also by a continuous line of mud banks solidly compacted against the outerside of the curbing. In some of the latest roads constructed by the county a "tie" is placed every 8 ft. under the pole foundations at right angles to the center line of the road. These ties are securely spiked or bolted to the piling supporting the side curbing or bulkheading and thus bind the two lines of curbing together, preventing the spreading of the roadway and at the same time carrying a part of the weight of the roadbed to the piling. After the pole foundations are properly laid, good soil is filled in between the lines of curbing until the required elevation is reached, after which shells and gravel are spread over the roadway until the finished surface is brought to an elevation of about 2 ft. above the mean high water level. The pavement that has given satisfaction on these roads consists of oyster shells spread 5 in. deep and covered with 4 in. of gravel.

Somewhat different methods from those given in the preceding paragraph were used in the construction of a road in Atlantic County, New Jersey. This road was constructed across salt meadows, the mud varying in depths from 6 to 28 ft. The surface along the line of the road was mostly a floating sod, varying in thickness from 2 to 4 ft.; below this was a semi-liquid mud resting upon hard pan. The latter, in a few places, was only 4 ft. thick, and below this was another stratum of soft mud. The first layer of hard pan was depended upon to support the roadway. The approaches to a bridge along the line of the road were piled, a water jet and hammer being used to put down the piles. In driving the piles the first resistance was met at a depth of 28 ft.; at 35 ft. this resistance disappeared and the pile with weight of hammer sank indefinitely. Accordingly the piles were only driven to a depth of 30 ft. The pit at this point, however, extended for only a short distance, and in most cases a solid bed of gravel, sand or clay was usually struck at a depth of from 10 to 20 ft. below high tide. After the line of road was located, sod banks 5½ ft. high, 12 ft. wide at the base, and 2 ft. wide at the top were built. This sod was taken from between the banks and was placed with the grass side out. The inside edges of the sod banks were 60 ft. apart. The space between the sod banks was then filled in with sand dredged from an adjoining bank and pumped through pipes for a distance of one-half mile or more. As the sand settled it pushed the mud sidewise until it reached an equilibrium or the sand rested on the hard pan. When the bed of sand was 6 ft. above the level of the meadow its weight was sufficient to displace the mud along the line of the road, and a good foundation was secured. There

were a number of silt ponds along the right of way of the road and at these points there was no sod for banks. Pine bulkheads were used at these places. After the sand fill had thoroughly settled the roadway was given the proper crown and surfaced with a coating of gravel.

Methods in a way similar to those previously described are sometimes used in Yukon Territory, Alaska, in constructing roads over frozen muck and gravel flats. The ground usually consists of a layer of frozen gravel, next a layer of frozen muck and on this a layer of moss. A bed of 3-in. poles is laid lengthwise on the layer of moss, then comes a layer of brush placed crosswise and on top is broken stone or gravel. The layer of brush is usually 1 ft. thick and the surface of gravel or stone is 6 in. thick. The top width of the road is 16 ft. in most cases. Such a road built over frozen ground costs about $3,200 per mile and can be maintained at much less cost than a road built along hill sides. In constructing roads of this type it has been found best to leave the moss intact under the bed of poles, as it protects the ground from thawing. The black frozen muck, having the consistency of solid stone, remains as a firm bed. The side ditches, usually 3 ft. deep, are cut either entirely in muck or partly in muck and partly in underlying gravel. These conditions vary with the thickness of the muck. The inside faces of the ditch are often banked with sod, thus furnishing an additional protection. In the construction of a side hill road it is necessary to cut into the moss blanket, and as a result the frozen muck is thawed out by the sun and seepage water and becomes a soft, slimy mass. The cost of maintaining such roads has been found to be so much greater than for roads on flat ground, that the latter are now constructed even if the distance between the termini is greater.

Compression of Marsh Soil. When a bank is filled on marsh land there is first compression of the lighter marsh material between the heavier filling, then a shrinkage of filling material, and, third, a gradual settlement of the embankment, compacting and displacing the softer marsh that sometimes continues for many years. Eugene R. Smith, in *Transactions American Society of Civil Engineers*, vol. 37 (1897), gives data on the compressibility of salt marsh at Islip, Long Island, N. Y., under the weight of an earth fill. This salt marsh (locally known as meadow) consists of a growth of salt grasses on mud just above the level of ordinary high tide. The mud consists of an accumulation of decayed seaweed and other vegetable matter, and is very soft and compressible. The sod forms a covering over the mud and distributes, in some measure, the pres-

sure due to the weight of the filling material placed above. The pressure on the mud from the fill increases the firmness of the mud by squeezing out the water.

The specifications called for a fill 3 ft. high above the ordinary level of the meadow surface or about 3.4 ft. above ordinary high tide. The work was performed by an 18-in. centrifugal pump dredge, dredging sand from Great South Bay adjacent and from a canal dug through the meadow. This sand was a very sharp quartz and weighed from 2,875 to 2,956 lb. dry and 3,037 to 3,118 lb. wet per cu. yd.

The percentage of compression of various depths of meadow sod ranging from 1.5 to 6.5 ft. thick during periods from 1 to 12 months are given in detail by Mr. Smith. The general average compression for all thicknesses was as follows:

Months	1	2	4	6	8	9	10	11
Percentage	10.0	13.1	15.1	15.9	16.9	16.6	16.2	16.7

Meadows averaging 2.7 ft. thick ranging from 1.5 to 3.5 ft. inclusive, varied from the general average by minus percentages ranging from 2.3 for a period of 1 mo. to 5.6 for a period of 11 mos. Meadows averaging 4.7 ft. thick, ranging from 3.6 to 6.5 ft. inclusive, varied from the general average by plus percentages ranging from 0.9 for a period of 1 mo. to 2.8 for a period of 11 mos. Meadows over 6.6 ft. thick and averaging 6.9 ft. varied from the general average percentage of compression by plus percentages ranging from 0.9 for a period of 1 mo. to 1.3 for a period of 11 mos.

Mr. Smith states that his experience in January, when the rise and fall of the tide was greater, indicated that great changes in tide level permitted an opportunity for the meadow to dry out and reduced its compressibility under filling.

Railway Embankments. These are seldom built in layers except when they are made by scrapers or barrows. For high fills the usual practice is to build out from the end or to dump from trestles. Consolidating during construction usually being impracticable, allowance for shrinkage must be made. This can be done in several ways:

(1) By raising the height of crown above the established subgrade by a percentage of embankment height.

(2) By adding additional width to the standard crown width.

(3) By combining methods one and two.

(4) By adding a shrinkage percentage to the height of embankment, computing a new slope distance for this corrected height, thus increasing the width between slope stakes.

The last method seems unusual and defeats the purpose of

shrinkage, as it adds width to the embankment where gravity and the action of the elements naturally provide it. In cases where sliding or sloughing is to be expected, it is better practice to increase the slope ratio.

While raising the height of crown places the material where it is most needed, it has the disadvantage of making temporary humps in the grade line. If the fill is on maximum grade the allowance for shrinkage may cause that grade to be exceeded to a serious extent until the ultimate shrinking has taken place. This leads to the practice of adding additional width to the crown, the extra material being used to raise the tracks after subsidence takes place.

In building a long, high levee, gravelly earth was dumped through a temporary trestle, and spread with a dragline scraper. The material was kept soaked with water from a pipe line on the trestle. For about 5 cts. per cu. yd. it was thus spread in layers and compacted. This is a relatively cheap method that might be used on railway embankments where subsidence is sufficiently objectionable to warrant the cost of consolidation.

Subsidence of Embankments on Soft Ground. This is usually treated by continuing to fill until either the soft material is entirely replaced or until it is sufficiently compacted to carry the required load. Hence it often happens that railroad embankments contain much more material than appears on the surface. The importance of discovering this hidden embankment in valuation work is obvious. F. J. Wright, in *Engineering Record*, Mar. 3, 1917, describes surveying work on the C. C. C. and St. L. Ry. to disclose the "lost yardage."

The depth to which the different fills had subsided ranged all the way up to 25 ft. The filled material also varied greatly, so that it was found expedient to use two methods in determining the slope of subsidence—(1) the excavation of test pits at the toe of the slope and (2) the drilling of test holes through the fill.

The fills tested by the excavation of pits were either those which had subsided a comparatively small amount or those made of rock and other coarse material, making drilling impossible. The pits were dug at the toe of the slope, from 100 to 200 ft. apart, between the points of no subsidence at the ends of the fill. The excavation of each pit was carried back several feet into the fill, the depth varying as the downward slope of the surface of the old ground toward the center of the fill.

Test pits were impractical in sounding fills which had subsided more than 8 or 10 ft. The presence of water near the surface of the marsh or bog made the test-pit method more un-

satisfactory. When these conditions were found, test holes were drilled down through the fill with an ordinary soil auger until old ground was reached. To facilitate drilling, pits were usually dug at the toe of the slope, in about the manner shown in Fig. 3.

The drilling outfit consisted of the following material: One 2-in. soil auger welded to a 6-ft. length of 1/8 x 1¼-in. galvanized-iron pipe, the upset end threaded for a 1¼-in. standard pipe; ten 5-ft. lengths of 1/8 x 1¼-in. galvanized pipe, threaded at both ends; three 5-ft. lengths of 3/16 x 2½-in. galvanized pipe (casing); eighteen 1¼-in. galvanized pipe sleeve couplings; two 16-in. Stillson pipe wrenches, and one length of 2-in. galvanized pipe

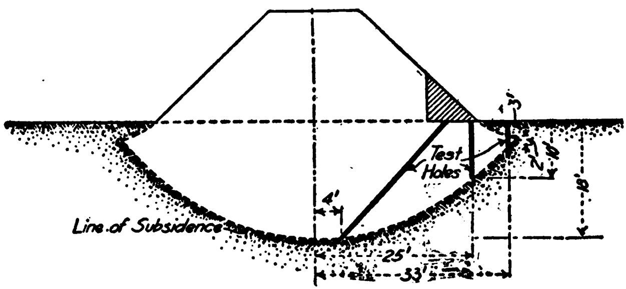


Fig. 3. Typical Arrangement and Depths of Drill Holes.

fitted with a standard 1¼-in. galvanized pipe tee at the center (handle).

When the test holes were less than 6 ft. deep, the pipe handle was attached to the end of the auger. In the case of deeper holes the pipe handle was removed and pipe lengths were added as the depth of the hole demanded, the auger being turned with the pipe wrenches. The pipe casing was used only in fills containing cinders, sand, or coarse gravel, and was driven down until it passed through the material causing the difficulty in drilling.

In putting down a test hole, the driller withdrew the auger at about every foot of depth, and the earth brought up was examined and removed. The drilling was continued until material was reached which could be identified with the surrounding land. In cases where the filled earth and old ground were similar as to color and formation, roots and twigs in the latter aided in distinguishing between them.

The estimated yardage due to subsidence of eight fills sounded

was 250,000 cu. yd. This work, which involved 1,090 lin. ft. of drilling and 270 cu. yd. of shovel work, was accomplished at a total cost of $305.

Subsidence Investigations, C. B. & Q. R. R. W. W. K. Sparrow, in *Engineering News-Record,* June 20, 1918, gives the following:

A hidden quantity of material 30% in excess of the apparent amount was found by the valuation department of the Chicago, Burlington & Quincy R. R. in a peat bog in northern Illinois. At a cost of $313 material amounting to 80,000 cu. yd. was found, mainly by means of test borings. The bog was under a 20-ft. fill which extended both ways from the bog. The entire extent of the latter was only 1,100 ft., and the appearance of the ground surface was no different from that on either side of it.

To ascertain the extent and the amount of subsidence, test

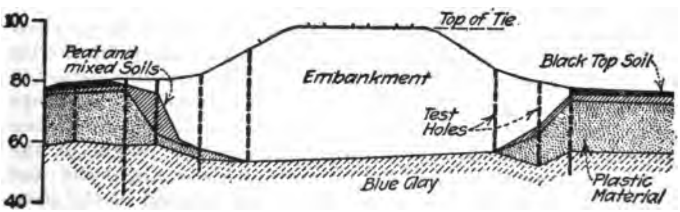


Fig. 4. Typical Cross-Section Near Midpoint of Bog.

holes were put down by means of a 2½-in. wood auger attached to a ¾-in. gaspipe cut into convenient lengths. Trenching was resorted to at a few points, but did not give as satisfactory results as the test holes.

Where undisturbed, the bog showed a top stratum composed of a black dirt which gradually turned into a stratum of brown crumbly material known as peat. Under this was a plastic mass, gray, which after a few feet turned to a greenish color. It was possible to push the auger through this stratum without turning it; the whole gave off a strong odor of marsh gas, and when the auger was withdrawn the hole closed at once. Under this mass a stratum of stiff blue clay was found, and at succeeding depths this material was found to become harder, with a tendency to contain gravel.

Tests on either side of the bog developed a different formation, in which no subsidence was found. The surface material was the same as for the bog. Under it a blue clay was found, containing streaks of yellow which gradually disappeared, leav-

ing the material exactly the same as that found under the plastic mass in the bog.

Fig. 4 shows the location of test holes, the strata revealed by them and the amount of hidden material compared with the visible embankment. The yardage of embankment above the apparent ground line within the limits of the bog was 61,300. The yardage of hidden material was 80,000, showing the hidden quantity to be 30% in excess of the apparent quantity. To obtain the data, four men, receiving a total of $19.55 per day, worked 16 days, this cost amounting to $312.80. Fifty-two holes were bored to an average depth of 21 ft., and 25 to an average depth of 6.6 ft. The cost of the survey per linear foot of hole bored was 24 ct. The cost per cubic yard of hidden material revealed was 0.4 ct.

Temporary Trestles. These are often used to carry construction track in building embankments. Dumping from them saves the use of a considerable number of men who would be required to raise the tracks with jacks from time to time if no trestle was used. Most of the timber used in trestles remains buried in the fill. Trestles are a frequent source of difficulty. They are always in danger of injury from rocks or boulders in the filling material. Subsidence of the ground due to the weight of the growing embankment frequently destroys their alignment and usefulness. So many factors enter into the question of the economy of using trestles that each case must be decided for itself. It is impossible to state any minimum height of embankment for which dumping from temporary trestles would be cheaper than raising the track.

Engineering News, Aug. 9, 1906, describes the method employed to raise an old embankment. Earth was first dumped from the old main track and spread with a Jordan spreader. New track was laid on the newly dumped material and the embankment widened to slope stakes by throwing the track. The new track was then thrown to the final center and raised by tamping. Thirty men handled 30,800 cu. yd. of fill in one month. Their pay at $1.75 per day was $52.50 daily or 3.4 ct. per cu. yd. A trestle would have released 22 men, making a saving of 2.5 per cu. yd. or 32 ct. per lin. ft. of embankment built, which was not enough to cover the cost of the 10-ft. trestle required. On a higher fill a trestle would have saved its cost.

Costs of Temporary Trestles. *Engineering and Contracting,* July 20, 1910, quotes D. J. Hauer in discussion of a paper on building embankments which was presented before the Am. Soc. of Eng. Contractors as follows:

In regard to costs, I might say that in building a large number

of temporary trestles, and keeping very accurate records, where logs could be obtained on the ground at from 3 to 5 ct. per linear foot, and carpenter wages were from $2.50 to $3.00 a day, my experience is that the cost of a trestle ranges anywhere from 1 to 8 ct. per cu. yd. Over low structures, where the amount of material to be dumped is not large, the cost runs frequently from 4 to 5 ct. per cu. yd., and maybe a little higher; although in one case, near Savannah, Ga., I erected a long, low temporary trestle, at an average height of 8 ft., for 2½ ct. a yd. But I was able to get my stringers by buying and reselling, so the cost was only $2 per thousand. For the short bents, placed on 18-ft. centers, I was able to get the timber off the right-of-way. But on that same work, where we were compelled to buy our longer timbers, the cost was about 3 ct. a cu. yd. for a trestle about 28 ft. high.

On one job in North Carolina, I erected temporary trestles, varying in height from 30 ft. to 50 ft., in some cases triple-deck in their framing, and they cost from 2½ ct. to 5 ct. per cu. yd. for the material placed in the embankment. The cost of timber was 3 ct. per lin. ft., and carpenters were paid $2.50 a day. The amount of iron was small, being in the bents mostly. The stringers and ties were not fastened with metal.

I have some costs of one structure, about 70 ft. high, where the price of timber was about 5 ct. a foot, and of labor $3 a day for the carpenter, and the average cost of the trestle was between 7 and 8 ct. per cu. yd. There were something like 150,000 cu. yd.

Dumping Trestles on the Southern Ry. *Engineering News,* Nov. 16, 1916, illustrates several trestles in use on the Southern Railway.

Railway fills are made chiefly by dumping from one or more lifts of trestle or by building one trestle and then jacking the track to grade. As is the case on most large grading jobs where several contractors are doing the work, both these methods are in use in grading the 50-mile second-track Southern Ry. relocation between Central, S. C., and Cornelia, Ga.

Half a mile south of Ayersville, Ga., the trestle for a fill on the new line is built on the side of the old 70-ft. fill. This trestle was not anchored very securely, as Fig. 2 indicates. In dumping the 12-yd. cars were backed out on the trestle very carefully and just far enough to dump clear.

The timbers, which are obtained near the right-of-way, are hauled to place and hoisted by hand, by ox team or by mules. Fig. 5 shows the design of a trestle at Seneca, S. C., in which some of the bents were wired together.

Two especially good examples of the trestle method and the

jacking method are found on this work. The heaviest fill is 150 ft. high, and it has been carried up more than 60 ft., to date, by jacking the tracks from the first 18-ft. trestle lift. This work

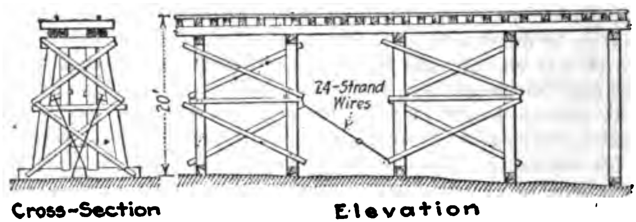


Fig. 5. Trestle at Seneca, S. C., Used in Heavy Fill.

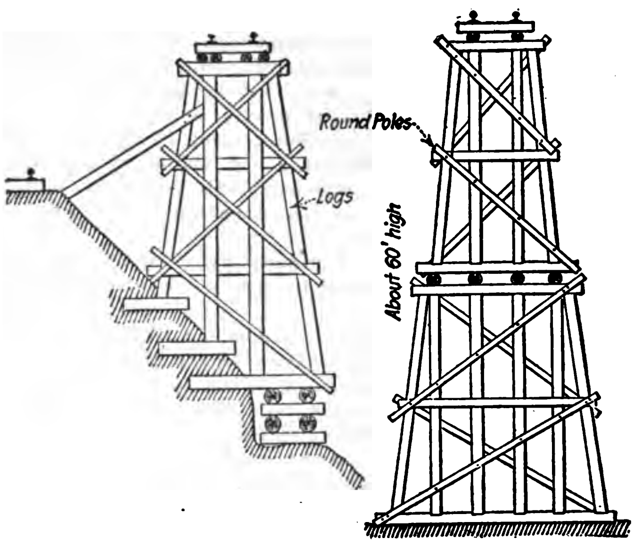


Fig. 6. Trestle Built on Slope of Old 70-Ft. Fill. Two-Story Trestle.

is near Toccoa, on the Lane section. Near Deercourt, Ga., a 105-ft. fill is being made from three parallel trestles of increasing height. Both these large fills are almost entirely borrow.

Cost of Two Dumping Trestles. John C. Sessen, *Proceedings*

of the American Railway Engineering and Maintenance of Way Association, 1907, gives the following:

These trestles were designed to carry a loaded train of 5-yd. dump cars before the trestle was filled, the engine being carried only after filling. Second-hand material, except bracing, was used. Two 8 x 16-in. stringers were used for 13-ft. spans. The stringers were recovered, the balance of the material was buried in embankment. Each bent consisted of two piles, cap and sway braces.

Name of Job	Big Shoal	Little Shoal
Length of trestle, ft.	2,961	2,142
Average height, ft.	40	35
Total cost of trestle	$9,007	$5,853
Labor cost per lin. ft.	$1.30	$1.22
Material cost per lin. ft.	1.74	1.51
Total cost per lin. ft.	$3.04	$2.73

Except as an approach to a higher trestle it does not usually pay to build trestles under 16 ft. in height. For trestles between 20 and 60 ft. in height, the cost of trestle per cu. yd. of earth is about the same.

Movable Trestles for Bank Construction. In *Engineering News*, June 12, 1902, Joseph Wright describes and illustrates "A Method of Bank Construction by Dumping from Movable Trestles." The bank was to be about 1½ miles long and 6 ft. high for a railroad, over practically level ground. A trestle was built in sections 17 ft. long; the side on which the earth was dumped being closely sheeted with plank. Each section of the trestle rested on two long wooden skids, so that one team could shift each section of the trestle when it became necessary to move. Let it be noted, however, that if the embankment had been much over 6.5 ft. high the pressure of the earth against the plank sheeting would have shifted the trestle without the aid of a team; and means would have had to be provided to keep the trestle in place. This is an ingenious method, and enables a very long embankment to be built without leaving any timber in the bank.

A method well adapted to similar conditions, but where the bank is high, is described and illlustrated in *Engineering News*, Jan. 16, 1902. A fill ¼ mile long and 60 to 65 ft. high was to be made over practically level ground. Instead of trestling, the contractor had a light movable steel bridge made with a span of 150 ft., and 14 ft. between the trusses, the weight being about 40 tons.

One end of the bridge was supported by the bank, on rollers; the other end was supported by a wooden tower or trestle 60 ft.

high, made with bents, each having three "stories." The tower was 16 ft. wide on top and 25 ft. wide at the bottom, and it rested on wheels running upon rails 25 ft. apart. Guy ropes prevented overturning from wind pressure.

By using block and tackle, one team of horses can shift the trestle with the bridge a distance of 30 ft. in three hours' time. A train of 12 dump cars (3 cu. yd. each) running on a 36-in. gage track is hauled by a locomotive.

Three cars are dumped at a time, then the train is shifted, and three more cars dumped exactly where the first three stood. This dumping in one place is supposed to pack the earth and prevent future settlements. Thus far settlements have not occurred. The material is clay, and the steam shovel, working night and day, is loading about 1,600 cu. yd. every 24 hr. Had a temporary trestle been built the cost for timber would have been double the cost of the movable steel bridge and tower.

These two methods of saving timber in trestling for fills (where timber is scarce) illustrate the possibilities of great saving in cost when the contractor has a full knowledge of his business — and a goodly share of ingenuity. The author would suggest that the first movable trestle method might be used even for very high fills, simply by building the fill up in layers of say 8 ft. thick the full length of the fill; and by so doing a more compact embankment would be secured.

Cost of Carpenter Work on Trestles. In building an embankment 16 ft. high across Otisco Lake, N. Y., the author used round unsawed timber with two posts in each bent; the caps were sawed and the beams between bents upon which the rails rested were also sawed timber that was saved and used again and again. In this way the cost of trestling was made very slight. With carpenter wages at 25 ct. per hr., and labor at 15 ct. per hr., the cost of framing and erecting the trestle was $6 per 1,000 ft. B. M., or about ½ ct. per lineal ft. of heavy timber.

Additional costs are given in my "Handbook of Cost Data."

A Wire-Rope "Trestle." V. L. Ingle, Jr., in *Engineering and Contracting*, June 1, 1910, gives the following:

Usually two methods are employed in making embankments where locomotives and dump cars are used. The first method is to lay the track on the ground, and, by dumping alternately to right and left, jack up the track until the required height is reached. This method is most economically employed where the ratio of length of embankment to height is 25, or more, to 1. The second method is to build a trestle and make the fill by dumping from it. Building trestles is expensive, and, if the material to compose the embankment contains a considerable pro-

portion of large rock or boulders, there is always the danger of carrying away a bent or otherwise seriously injuring the structure.

On a piece of heavy railroad work in the South where the embankments were high one of the embankments to be made contained about 115,000 cu. yd., reached a maximum height of 57 ft., and was slightly over 800 ft. long, from grade point to grade point. To build a trestle would have cost between $6,000 and $8,000, and, as the material to make the fill was mostly rock, the chances were very great that a part of the structure would be carried away before the completion of the work. To avoid the necessity of constructing a trestle, the following scheme was adopted:

The cuts at both ends of the embankment were opened up in

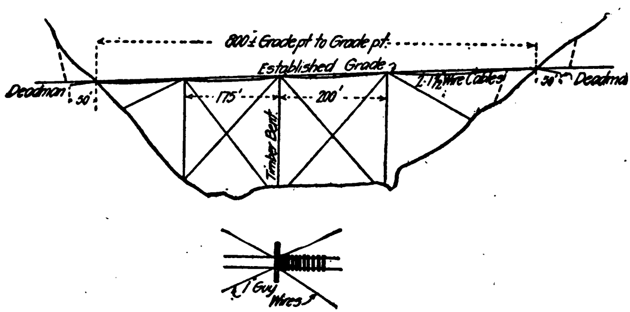


Fig. 7. Side View of Wire Rope Trestle for Making Large Fill.

the usual manner with carts for about 60 ft., as indicated by the dotted lines in Fig. 7. At points, approximately 50 ft. from each grade point, deadmen were sunk, and two 1½-in. wire cables, spaced 3 ft. 6 in., were stretched from one to the other and hauled as taut as possible. At points about equally dividing the fill, three timber bents were erected, as shown in Fig. 7. These bents were made from timber cut on the right-of-way. Their construction is shown in Fig. 8. Caps were about 8 x 8 in. x 6 ft. and sills about 10 x 10 in. As this timber was cut on the ground, the dimensions varied slightly.

In erecting, the tops of the caps were brought to the established grade line, and the sills were sunk in a trench 3 or 4 ft. deep, which was backfilled with rock or earth. This steadied the bents and prevented their kicking out at the foot, under the impact of the dumped material. From the caps, 1-in. guy wires

were run out at angles of about 45°, in order to clear the dumping of material as far as possible, and fastened to deadmen. The main cables were then fastened to the caps by wire lashings and the ties placed on them, every third or fourth tie being lashed to the cables. The rail was then laid on the ties, brought to the established grade line, and they were laid far enough ahead to accommodate the length of train used.

The method of operation was as follows: A train of loaded cars was backed onto the approach fill, and, at the point where the cables left the fill, were dumped, the first car on one side, the second on the other side, alternate cars on alternate sides, until the entire train was unloaded. The train was then run back on the approach fill and the cars righted. Dumping the cars on

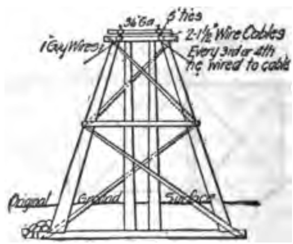


Fig. 8. Details of Timber Bent for Wire Rope Trestle.

alternate sides balanced the weight on the cables, prevented the overturning of the train and made the fill about equal on both sides of the track. All cars were dumped before their loaded weight came on the cables, only empty cars being supported thereon. Little or no shoveling of material was required, most of it sliding to the bottom of the fill, and what little remained was generally used in jacking up the track. As the bents were approached, more or less care was exercised to prevent their being injured, but no more so than on any other trestle.

The work was carried forward in this manner until the ravine had been spanned, after which it was widened out in the usual way.

In building the trestle it was assumed that the deflection of the cables at the center of a bay would be about 5% of the span, but, by jacking up the track as the embankment was made, the deflection was reduced to about 3%. When dumping at the center of a 200-ft. span this gave about a 6% grade for a dinkey engine to start an empty train on, and was not prohibitive.

The plan described left very little material in the dump, saved the main cables, guys, and caps, and was much more quickly and cheaply carried out than would have been the erection of an all timber trestle. The writer left for other work before the completion of this fill and so has no exact data as to cost. Figuring maintenance at the same rate as during his connection with the work, and barring accidents, the cost should have amounted to about 3 ct. per cu. yd. of embankment.

A Suspension Bridge for Making Fills. *Engineering and Contracting*, May 19, 1909, gives the following. The bridge consists of two towers, a fixed standard cableway tower at the far end of the embankment, and a portable steel structure on the advancing end of the embankment, both supporting a suspended track. The movable tower is 25 ft. wide across track, 20 ft. wide in the direction parallel with the track, this width decreasing to 12 ft. at the top, which is some 70 ft. above ground. The tower (Fig. 9) moves on a 20-ft. gage track, laid on the fill. The movement is by skidding, horizontal steel plates being attached to the feet of the tower legs. At the top of the tower are special saddles for the cables.

The cables are spaced 12 ft. apart and extend from an anchorage back of the stationary tower to an adjustment back of the portable tower. They are 2¼-in. wire rope cables. They carry suspenders which support the track platform; these suspenders are spaced 12 ft. apart on each cable, and are kept to proper spacing by connecting bars (two 4½ x ½-in. steel straps). Each suspender consists of a 6-in. trolley sheave having strap hangers on each side which support a single-sheave block. A ½-in. steel cable is run through this block and supports in its bight another single-sheave block, which attaches to a staple bolt. The staple bolts of successive hangers run through and support the platform girders. The block and tackle construction of the suspenders permits their length to be adjusted vertically so that the track platform can always be kept level. The platform girders are across-track, one end being supported by the suspender from the right hand cable and the opposite end being supported by the suspender from the left hand cable. These girders carry two lines of stringers on which are laid the ties and rails of the dump car track.

In operation the fill is started at the portable tower, the cars being backed out from the solid embankment onto the suspended platform track and dumped, a car at a time, just at the top edge of the fill. By this arrangement practically only empty cars are carried by the suspended platform. At the start of work the platform is suspended quite close to the tower, but as the em-

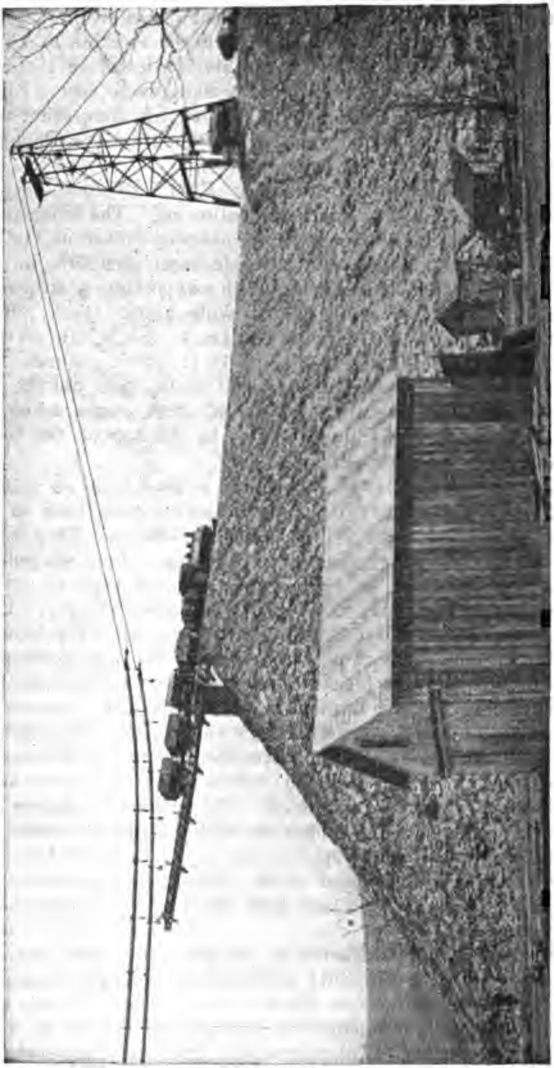


Fig. 9. Suspension Bridge Making 80-Ft. Fill on Delaware, Lackawanna & Western Ry.

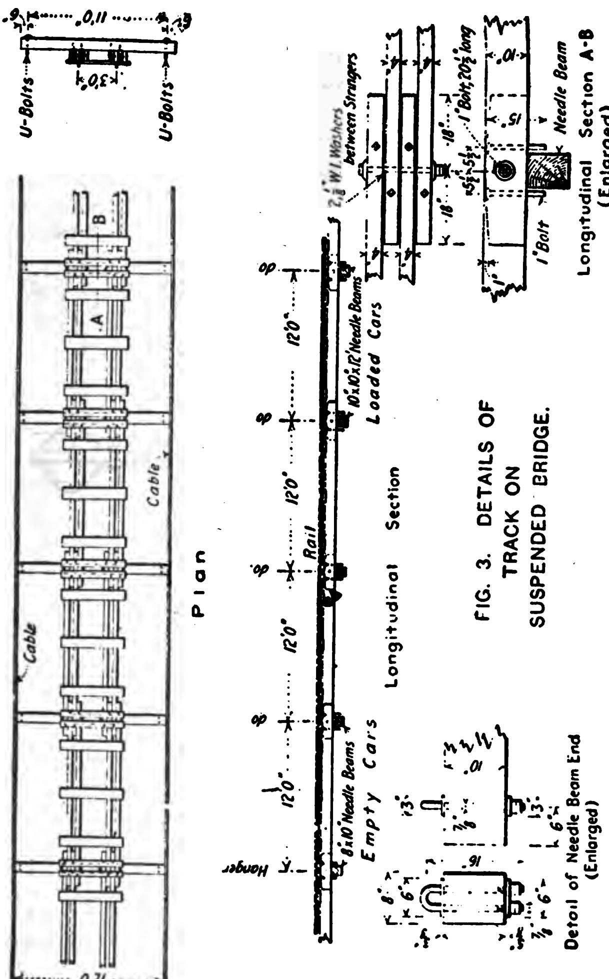


Fig. 10. Details of Track on Suspended Bridge.

bankment is filled out the platform is moved away from the tower.

This aerial cable bridge is handling some 1,200 cu. yd. of material per day, this being not the limit of the bridge, but the maximum which can be excavated daily. This plant requires no

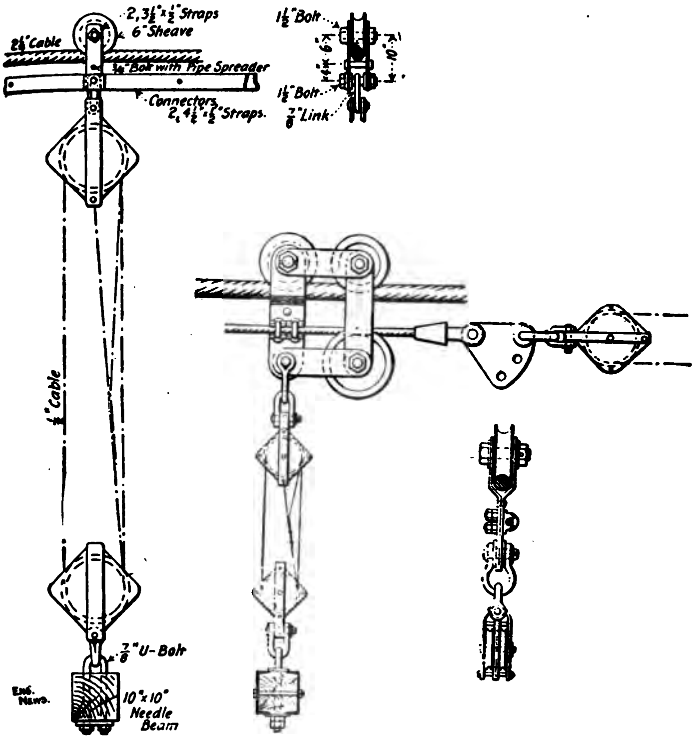


Fig. 11. Details of Cable and Hanger.

power other than that of the locomotives used for hauling material trains. It is readily dismantled and transported. Its salvage value is large.

Further details of this cableway and suspended bridge are given in *Engineering News*, Apr. 22, 1909, as shown in Figs. 10 and 11.

Details of a Suspension Dumping Bridge. *Engineering News*, Nov. 20, 1913, gives the following:

Each tower is composed of a pair of A-frames, braced together and carrying a heavy built-up cap. Upon the caps are placed cast-iron saddles for the two cables, which are of plow steel, 2 in. diameter. On the anchorage sides, the cables are led to deadmen embedded in the ground about 150 ft. from the tower. Near the top of the tower they are connected by a 1-in. steel tierod, and beyond this they diverge at an angle of 30° to the anchorages. The cables are 10 ft. apart, and at intervals of 10 ft. there are suspenders or hangers secured to hooks clamped on the cables.

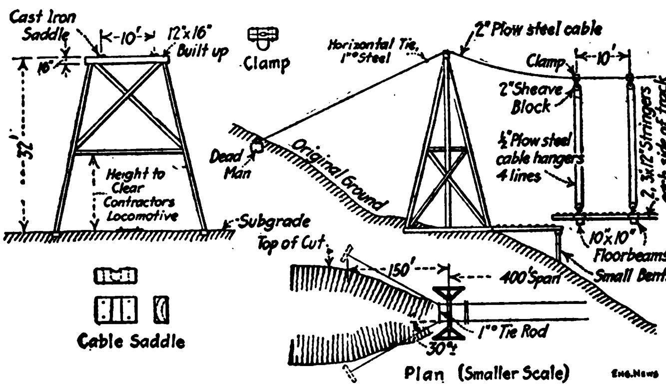


Fig. 12. Suspension Dumping Bridge for Building Embankments; Louisville & Nashville R. R.

These suspenders are four-line tackles of ½-in. steel cable, having the upper block hooked to the clamp on the main cable and a lower block hooked to a belt in a floorbeam 10 x 10 in. The stringers for the track ties rest on the beams. Each stringer is made up of two timbers 3 x 12 in. The track is laid for a length sufficient for six small dump cars. The first section of the floor is supported upon small bents, the bridge floor beginning where the height becomes too great for such bents.

A Suspension Bridge and Its Cost. J. D. Mooney in *Engineering and Contracting*, Oct. 2, 1907, gives the cost of a "cable trestle" used in making a 175,000 cu. yd. fill on the Lake Erie and Pittsburgh Ry., at less than 1 ct. per cu. yd.

Roebling galvanized bridge cable, 2¼ in., was used. The anchors were 400 ft. apart, and an A-frame was erected to support

the two cables in the middle; this made each span 200 ft. The anchor at the north bank consists of a log, 18 ft. long, 24 in. thick, imbedded in solid rock. Two eyebolts screw into the log and are fastened by heavy nuts over 8-in. cast iron washers. Connecting with these eyebolts are two 10-ft. chains with 10-in. links made from 2½-in. iron. These chains were put in to keep the cables from twisting by covering the chains with heavy weights. Two 3-in. turnbuckles, with a spread of 3 ft., made the connections between the chains and the cables. The cables were leaded into the turnbuckles. These turnbuckles, which were forged especially for this work, were used to take up the slack in the cables. The anchor at the south end consisted of a log, 25 ft. long and 24 in. thick, placed in a new fill of sandstone, 10 ft. deep. Three-inch planks were driven in front of the anchor, two eyebolts, 22 in. long and 2½ in. in diameter, were screwed into the anchor log and fastened with nuts over cast washers, 8 in. in diameter and 2 in. thick. The eyebolts connected with clevises by means of 3-in. pins. The cables were leaded into these clevises. A rise of 1 ft. in 3 ft. brings the cables up to grade and to the end timber supports.

The A-frame which supports the cables in the center is made of two bents of four timbers each, total height 92 ft. The lower 50 ft. of the frame is made of 10-in. round timbers, and the upper 42 ft. of 8 x 8-in. square timbers. The cables on the top of the A-frame are 8 ft. above grade. The bents rest on 10-in. mud sills. They have a batter of 1½ in. to a foot. The frame is 32 x 26 ft. at the bottom.

A train consists of from six to twelve 4-yd. cars. These are emptied at the south end of the ravine and are pushed out onto the cableway as fast as they are emptied. The car rails are spiked to ties which rest on stringers. These stringers rest on 8-ft. logs fastened to the cables with U bolts. The cables are 7 ft. apart. Most of the fill is being made from a sandstone cut about a half mile distant. This sandstone has a slope a little steeper than 1½ to 1.

The following is the actual cost of the cableway:

1,000 ft. 2¼-in. Roebling galvanized bridge cable....	$ 600.00
Eyebolts, 2½-in., with clevises, for both ends........	108.30
2 turnbuckles at north end, 3-in.	120.00
2 chains at north end, 10 ft. long, 2½-in. iron.......	62.40
4 cast washers, 8 in. dia., 2 in. thick	2.46
Timber for A frame. (All other timber was obtained on ground.) Upper was 42 ft., 14-ft. timber, 8 x 8 in. All bracing and cross ties.	
3,200 ft. at $34 per M. (delivered)	108.80
Lower 50 ft., round timber, 56 ft. long, bought in tree	32.00
Team work for hauling round timber and pulling timber to place for erecting	65.00

Carpenter labor on A frame and end bents on bank	231.40
Time of superintendent	60.00
Common labor:	
Digging trenches for anchors and putting up cableway	112.00
Nails and iron in A frame and bents	29.40
Total cost of cableway	$1,531.76

A conservative estimate on the probable cost of a timber trestle for this opening, figuring on square 8 x 8-in. timber cut from native timber, gives the following cost:

98,000 ft. B. M. (including posts, caps, bracing, stringers, etc.) at $26	$2,548.00
Labor putting up trestle, $6 per M. ft.	588.00
Spikes	98.00
Drift bolts	40.00
Total estimated cost of trestle	$3,274.00

The wages were probably about $3 for carpenters and $1.50 for laborers per 10-hr. day.

Dragline Excavators for Railway Grading. *Engineering and Contracting*, June 4, 1913, gives the following:

In double track construction, on the Chicago, Milwaukee and St. Paul Railway, between Andover and Groton, S. D., a fill 5 miles in length and averaging 20 ft. in height was made from natural surface to subgrade by means of dragline buckets which took the material for making the fill from side borrow pits. By this method slightly over 900,000 cu. yd. of material were placed in the fill in three months' time. At times as many as five machines were in operation. The booms of these machines ranged from 50 to 100 ft. in length. When in service the buckets of the machines were dumped, on the average, once a minute. The buckets used ranged from 2 to 3½ cu. yd. capacity. The largest machine made 3½ cu. yd. of fill per minute when in service.

This method seems to have a wide range of usefulness on railway work.

Haulage Equipment Eliminated by Dragline Excavators. *Engineering News-Record*, June 28, 1917, describes work on the Lorain, Ashland & Southern R. R., south of Wellington, Ohio. Nothing heavier than an 8-ft. cut was met on the first three miles. The dragline machine borrowed for the fills and wasted the cuts, swinging about 60 ft. of each end of each cut onto the adjacent fill. On the fourth mile, however, a cut 3,000 ft. long, 1,100 ft. of which averaged 19 ft. in depth, threatened to displace the dragline for other equipment. The material from this cut could not be placed in embankment economically and so was wasted.

The dragline in making the cut rode the center line, swinging the material into spoil banks on both sides. Only one move through the cut was required.

The dragline worked to a 0.57% grade, and on a 40-ft. curve the entire distance and handled approximately 40,000 yd. of heavy, yellow clay and blue gumbo during the six weeks required to complete the work. The slopes were cut from a 20-ft. base one to one and required no hand dressing. Some sliding due to frost action has occurred, but the work compares favorably with similar work done by steam shovel.

The south approach is a fill 2,300 ft. long, with a maximum height of 28 ft. built on a temporary grade of 0.7%. About 48,000 cu. yd. of material was borrowed from pits on either side, having widths of from 30 to 80 ft. and a maximum depth of 14 ft. Two moves through each pit were made, except for a short distance at the small end of the fill. On the first move, near the outside of the pit, the machine took out the material and placed it about halfway to the center line. On the second move this material was recast into the fill and the remainder of the pit made. At the high end of the fill during the second trip the machine climbed the side of the fill in order to cast to the top.

From 10 to 20% was allowed for settlement, as a great part of the material handled was from low-lying ground saturated from spring rains. An early and thorough settlement of the fill occurred, and only ordinary maintenance attention has been required since. The land purchased for the borrow pits cost $250. The expense of temporary trestles was saved; and although some of the dirt was handled twice, the dragline did away with the usual transportation equipment and force.

Building Railway Embankment with Hydraulic Dredges. *Engineering and Contracting*, in the issue of Feb. 9, 1916, gives the following:

The method described is employed by the Chicago, Burlington & Quincy R. R. for building embankment across sloughs on line rectification along the bank of the Mississippi River. Referring to Fig. 13, where the fill first appears above water, shields 10 ft. long and 2 ft. high are placed on each side as indicated for one side only at a. The sand is allowed to deposit until it is filled in as at b. Sand from inside the shield line is then shoveled over against the backs of the shields on the desired 2 to 1 slope, and the shields are jacked up as in c. When the fill again nearly covers the shields, the operation is repeated, and again a third time when the fill is about 3 ft. deep as in d. The whole shield line is then moved in about 6 ft., and similar operations follow

until the completed embankment has reached grade with a top width of 34 ft. for double track. One foot is the usual allowance for shrinkage, although in some cases more has been deemed necessary. E. R. Stevens states that this dredge embankment is 35 to 50% cheaper than steam shovel work.

An earlier account of this work published in *Engineering and Contracting* says:

On shore, about 12 to 20 men are required to handle the discharge pipe and the shields or guides. The shields are pieces of sheet iron 18 in. wide and 16 ft. long which are placed on edge in the sand at different locations so that the discharge will be held in little ponds until the material has settled. The handling of these requires considerable experience in order to

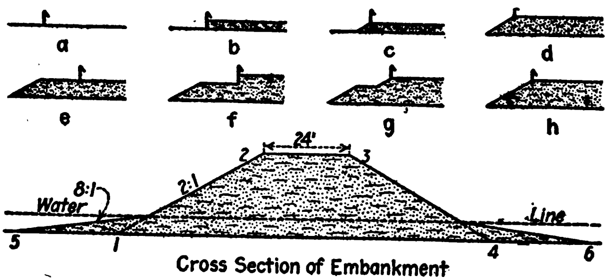


Fig. 13. Building Embankments with Hydraulic Dredge.

get the best results. The rate of output depends considerably upon the control of the discharge, so that the material will settle properly. The handling of the pipes must be done quickly so that the pumping can be as nearly continuous as possible.

The output of the dredge varies from 3,500 to 4,500 cu. yd. per day of 24 hr. The conditions for dredging are ideal, the heavy sand pumps easily and settles readily and no unusual difficulties have held up the work so that its cost has been very low. The embankment had to be leveled by teams before laying tracks.

Building Approach Embankments, Columbia River Bridge. The following abstract of an article by E. E. Howard in *Engineering News*, Jan. 27, 1916, is given as it offers an excellent illustration of the sheerboard method of retaining hydraulic fills. About 2 miles fill were built, averaging 20 ft. in height. See Fig. 14.

The contract was let to the Tacoma Dredging Co., of Tacoma, Wash., at its bid of 13.24 ct. per cu. yd. of the net volume in

place. This company moved its dredge to the site, installed pipes and pumped in the first sand on June 9. By Nov. 20 all of the embankment south of Oregon Slough had been placed — a total net volume of 821,000 cu. yd. The placing of this material occupied 160 days, or an average of about 5,000 cu. yd. a day. The material remaining in the embankment is a medium-fine sand, sharp and clean.

Method of Making Excavation. The material was excavated from the Oregon Slough by means of a suction dredge of usual type, with a cutting head, and was transported to place by being pumped through a line of pipe 24 in. in diameter. The operation was by electric power from the high-voltage lines of the Portland Railway Light and Power Co. The main pump on the dredge was operated by two 500-hp. motors connected to the

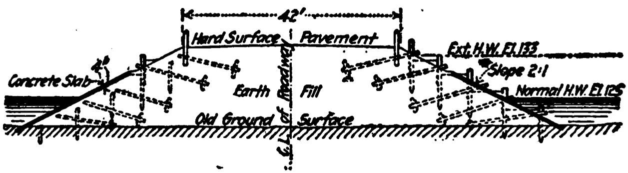


Fig. 14. Bulkheads for Retaining Hydraulic Fill for Embankment Approach to Columbia River Bridge.

pump by rope drives. The pump was of capacity to give a discharge through the 24-in. pipe at a velocity of 12 to 15 ft. per sec. Operation continued 24 hr. per day during the time specified, and the dredge was actually running about 14 hr. per day. For periods of a few hours at a time the dredge pumped as much as 1,000 cu. yd. per hr. There was of course a very considerable runoff of sand from the embankment, as well as a certain amount of fine material which flowed away with the waste water, and it is estimated that about 250,000 cu. yd. more than the above net amount was transported. The discharge-pipe line was extended to a length of about 4,000 ft., working from the dredge alone. For the greater distances a booster pump was installed in the line to give additional impetus. This pump was operated by a single 1,000-hp. motor operating with considerable overload. The dredge and booster pump together transported through a maximum length of 9,000 ft. of pipe. Such long-distance dredging into an embankment so comparatively narrow and high is believed to mark a record for work of this character. The pipe was of the ordinary riveted variety with slip joints made of

7-gage material on the pontoons and of 10-gage material elsewhere. It was moved about by teams and wagons.

Timber Bulkheads for Earth Backing. The embankment was built up in steps by the use of timber bulkheads (Fig. 14). These were built of 6 x 8-in. posts, about 10-ft. centers, supporting 2 x 12-in. sheathing, surfaced both edges. The sides of the embankment were built up by these means in steps 8 ft. wide and 4 ft. high. The first bulkheads were placed upon the natural ground surface by driving in the 6 x 8-in. posts with a hand maul and setting the lower plank into a small trench so that the bulkhead sheathing extended perhaps 8 to 12 in. below the ordinary ground surface. When the sand had been filled in about the top of such first bulkheads, posts for succeeding bulkheads were set in place and the lower plank placed so that it extended about 12 in. below the top of the first bulkhead below. These posts were tied back into the embankment by 2 x 6-in. ties spiked on near the top of each post and extending back to a short post, in front of which were placed a few pieces of lagging to offer additional resistance. The pipe was laid to discharge into the middle of the embankment so marked and was carried forward from the river, bringing the embankment up to the final grade and working away from the dredge. A framework of baffle-boards was placed under the discharging end of the pipe, causing the water to spread out and spill over the ground below and run forward, distributing the different sizes of material as the velocity decreased. At some convenient low point there was provided an outflow down the side of the embankment, for which the steps of the embankment were paved with plank to prevent wash.

After sections of the finished embankments became thoroughly drained as the work proceeded, the posts of the bulkheads were cut away and the planks removed and carried forward for repeated use. Parts of the posts and of the 2 x 6-in. ties therefore remain in the embankment. The finishing of the slopes was done by hand with shovels, and the successive steps were so located that the upper corner of each step filled into the lower corner of the step below, to provide the proper slope. The actual pumping and transportation of the sand in the hands of these contractors were the simplest parts of the work, and they found it economical to permit a very considerable wastage of material where a reasonable amount of such wastage saved in the construction of bulkheads.

Filling Trestles by Sluicing. Data on this will be found in Chapter XVIII. This is so cheap and satisfactory a method of building embankments that its possibilities should be thoroughly

investigated before any other means of moving earth are considered.

Additional information on filling land with material pumped by dredges will be found in Chapters XV, XX, and XXI.

Supporting Construction Track on Ice. According to *Engineering News*, Feb. 26, 1903, embankments over a slough, 500 ft. wide, on the Illinois and Mississippi Canal, were built during the year 1903 by carrying the construction track on ice. The slough consisted of very soft mud, overlain by 2.5 ft. of water. The embankment was 100 ft. wide on top and 14 ft. above the water. As ice covered the slough no trestle was constructed, but the railway track was laid directly on the ice. Short trains of cars were brought down and dumped three at a time, one on each side, until a bank was formed. The train was composed of 18 cars as a rule, but only 6 loaded cars were put on the ice at any one time. The ice settled under the weight of the fill, but the embankment was raised as fast as the ice settled.

At Stillwater, New York, the construction plant on part of Contract No. 68 of the New York State Barge Canal was conveyed across the Hudson River, a distance of 1,000 ft., by building a track on top of the ice. A full description of this crossing is contained in *Engineering and Contracting*, June 9, 1909.

The nearest railway station to the site of this plant was 6 miles away, and to avoid the necessity of hauling the plant overland for that distance, the contractor conceived the idea of delivering it by trolley on the west bank, and carrying it across the ice. The heaviest single piece was a 70-ton steam shovel, which could be stripped to about 45 tons by the removal of the boom and dipper. There were also three locomotives each weighing 18 tons, stripped to 15 tons. In addition there were hoisting engines, dump cars, drills, etc., some pieces weighing as much as 12 tons. On Jan. 12 when the machinery was delivered at the river bank, the ice was only 9 in. thick. It was increased to a thickness of 10 to 14 in. by cutting holes in the ice and pumping water upon it.

For spreading the weight over a wide area, 8 x 10-in. yellow pine timbers, 24 ft. long, were placed beneath the narrow-gage railway spaced 15 ft. apart. In each space were placed two 8-in. x 8-ft. ties, thus making the supports 5 ft. apart. At the west bank, where there was an abrupt descent, the ties and long timbers were spaced much closer. The supply of 24-ft. timber was not sufficient to cover the whole distance and near the west bank there was a stretch of 150 ft. over which the track was supported by ties alone, spaced 2.5 ft. apart.

A hoisting engine was first hauled across and placed on the

opposite bank. A cable, 1,000 ft. long, stretching from this engine to the opposite bank was used to pull over the loads. By taking several turns with this cable around a spool on the drum shaft, the various machines could be transported while the men were on shore, and it was not necessary to risk the life of some one upon the ice when the heavy loads were being carried. Moreover, when once started, the loads could be quickly hauled across. It took about 4 min. to haul over a single locomotive. Under the weight of a locomotive the ice sank down from 6 to 7 in. and formed in wave-like undulations, and there was also a shattering and cracking.

It was determined that a load of 15 tons appeared to be the maximum for ice 10 in. thick. The steam shovel was therefore taken over the highway for a distance of 6 miles, involving a week's labor. Fortunately, there was almost no snow on the ground and a thin layer of ice covered the surface. It was thus possible easily to haul the rails and to lay the track without ties, a few flat iron rods holding the rails in position. The shovel was moved for about $100 per mile.

A Scow Bridge Instead of a Trestle. A scow bridge was used in the construction of the Falcon River Dike, Winnipeg District. This device was illustrated in *Engineering News*, Feb. 4, 1915. It is claimed that the successful bidders saved over $25,000 by using the scow method as compared to the cost of using trestles. The contractors used two scows in tandem. The track on the boats consisted of 90-lb. rails on a frame-work whose sills rested on, but were not fastened to, the deck. To move forward, the scows were outhauled under the rail-supporting frames by a cable passing forward over a snatchblock at the outer end of the rail and back to the dinkey. Then the in-shore ends of the 90-lb. rails were moved to the outer end of the scows in the new position, and the gap filled in with regular 60-lb. rail as used in the rest of the supply track on the finished fill. The dike, 8,000 ft. long, containing about 230,000 cu. yd. of gravel, progressed rapidly, being practically completed in four months. The greatest depth of water was about 25 ft. Material was obtained from a gravel pit adjacent to the north end of the dike.

Engineering News, Apr. 1, 1915, gives the following relative to a dumping platform for disposing of material on the breakwater and part of the harbor work at Halifax, N. S. This platform, Fig. 15, consisted of a scow held by water ballast to constant level in spite of the tide. A plate-girder bridge, 40-ft. long was mounted at its forward end on a barge 40 x 8 ft. in size, and at its rear end on four or five cross-ties laid on the

outer corner of the embankment. The spoil was brought in 16-yd. dump cars and dumped directly from this bridge. Three or four cars at the head of a train were run on the bridge, dumped and returned. The track was continued across the scow as a tail track. When the embankment had been built up high enough (4 ft. above mean water) in the space spanned by the bridge, the scow and bridge were simply hauled forward until the bridge

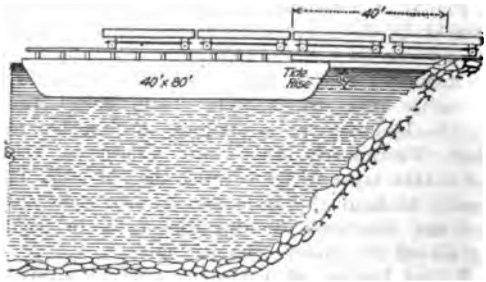


Fig. 15. A Scow Bridge.*

came to a new bearing on a new outer point on the embankment, and the process was continued. The tidal rise was about 6 ft. To keep the bridge level, water ballast tanks were provided in the scow. These were pumped full as the tide rose, and pumped out on the fall of the tide, keeping the dumping bridge level with the embankment.

Placing a Railroad Fill from a Pontôon Bridge. *Engineering Record*, Jan. 31, 1914, gives the following:

In the double-tracking and grade-revision program being carried out by the Chicago, Milwaukee & St. Paul Railway in South Dak. a fill was built across a lake about 1,200 ft. wide, averaging from 30 to 40 ft. deep. The bed of the lake is a soft and seemingly bottomless muck, test piles driven to a depth of 120 ft. indicating no firmer material.

The contractor, the Cook Construction Company, of St. Paul, intending to make the fill from side-dump cars, built a trestle across the lake, using 90-ft. piles. When filling was begun the weight of material forced the trestle out of line, and in fact tore it to pieces in two or three places. New piles were driven with the same result, and this happened five or six times.

Two scows were then built, and 60-ft. timbers were provided for stringers to carry the construction track. The scows were so placed that one set of timbers spanned from the bank to the

first scow and another set reached from scow to scow. The filling was dumped at the head of the bank, the empty cars being pushed ahead on the outer span. When the new embankment reached the scow the inner span and that scow were moved ahead. The scheme has worked very successfully.

Constructing a Fill with a Floating Trestle. A novel method of constructing a fill across Patterson Lake on the Northern Pacific Ry. between Tacoma and Tenino, Wash., is described in *Engineering News*, Mar. 25, 1915. The width of the lake measured along the center line was 1,350 ft. Originally it was intended by the contractors to make the fill across by dumping from a trestle, using three-pile bents with piles approximately 80 ft. long. Near the center of the lake they drove four test piles, 115 ft. long, and at this point it was necessary to cap the piles above the water and place frame bents on them in order to get the necessary elevation for dumping. For this construction four-pile bents and four-post bents were used.

The soft mud of the lake bottom heaved as the fill was deposited, throwing the fill out of line and lifting the piles bodily so that the trestle collapsed, and the mud rose above the surface of the water for a considerable area. The trestle was then held in place on log floats and these were later replaced by pontoons carrying a trestle of framed bents, as shown in Fig. 16. Sloping aprons extending from the trestle to the sides of the pontoon to deliver the material to the sides. This floating trestle was kept ahead of the end of the fill, being connected to it by a 60-ft. span of trussed timber stringers.

One steam shovel, loading into 12-yd. standard-gage air dump cars, started filling at one end on Feb. 25, 1913. On June 11 another shovel with 4-yd. narrow-gage dump cars replaced this machine, and the former shovel was moved to the other end. The material was mainly gravel and sand. For a single-track fill 761,000 cu. yd. were required. Afterwards, 72,000 cu. yd. were added to widen this road to double-track. This additional work was completed June 25, 1914.

Cost of Widening Embankments. *Engineering News*, Oct. 27, 1904, gives an abstract of a committee report presented at the annual meeting of the Roadmasters and Maintenance of Way Association, 1904, from which the diagrams here given are taken. The assumption is that material for embankment is to be obtained by ditching and widening cuts. The diagram, Fig. 17, can be used to study the relative costs of different methods of doing this work. The second, Fig. 18, can be used to advantage only in determining whether it is cheaper to make a long haul from the point where ditching is being done, than to waste the

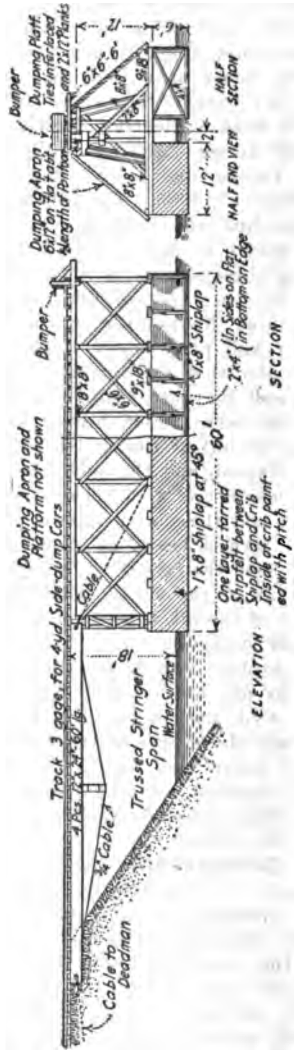


Fig. 16. Floating Dump Trestle on Pontoons.

material obtained from ditching and obtain the material for widening banks from a more convenient location.

By examining the diagram in Fig. 17 it will be seen that the cheapest method of ditching where the material is to be used in widening embankments, and where such work is not done by simply casting across one track, is by a machine ditcher, provided the machine is so designed that it can load and dump 5 cu. yd. in not to exceed 2½ min., exclusive of running time, and can be operated by three men besides the train crew, and if the

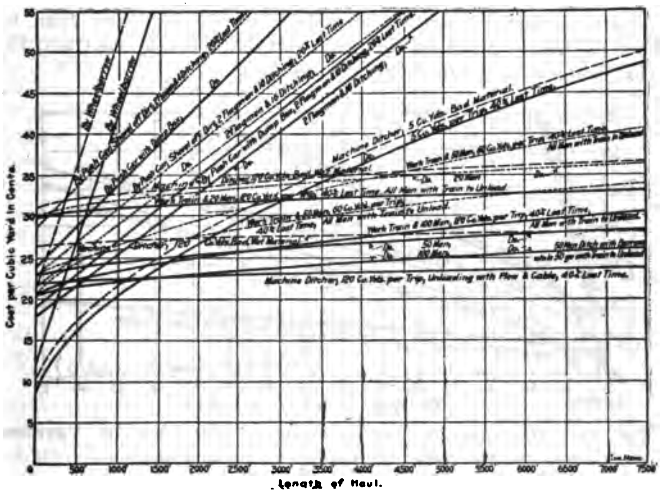


Fig. 17. Diagram of Costs of Railway Ditching by Various Methods, Haul up to 7,500 Ft.

conditions are such that such a machine can be used up to a haul of some 1,200 or 1,300 ft. in very fair digging, or up to some 1,900 ft. in bad, wet digging. From this point on, a properly designed machine ditcher, so arranged that it can load a full train of material, used in conjunction with a plow and cable or other method for quick unloading, can be worked most economically. In both these cases of machine ditchers, it is assumed that the machines will be used enough each year to bring the cost for interest and depreciation down to the estimate given in the appendix, the number of yards handled having to be greater than estimated in case a more expensive machine is used than estimated on.

In case a machine ditcher is not available, a study of the diagram will show the relative cost per yard by various methods, provided the traffic is such that the actual working time of work train is only about 6 hr. out of 10 hr. the men are assumed to work each day.

Team Work. On light work banks can be widened very economically with teams and scrapers. This method can also be used to widen the base of heavy embankments, the filling being afterwards completed by work train or other means. The filling being compacted by the movements of the teams over it is less liable to settlement and unites closer to the old bank than by other methods. Work of this kind is usually let by contract, the price being from 14 to 25 ct. per cu. yd.

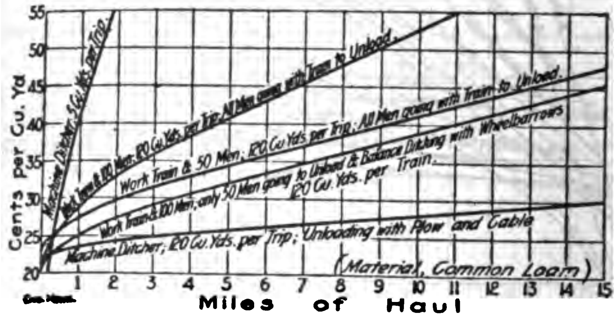


Fig. 18. Diagram of Cost of Railway Ditching by Various Methods. Hauls up to 15 Miles.

Casting. The cost of ditching by casting may in fair digging be taken at 10 ct. per cu. yd., where one cast will place the material in a suitable final location. If necessary to use one platform by which the material can be raised 6 ft. with the first and 4 ft. with the last handling, in order to place it far enough from the edge of the cut, the cost for such material will be increased about 6 ct. per yd., or to a total of 16 ct. per cu. yd. A description of a simple portable platform is given under the heading "Work Train and Hand Loading." In both of these cases the material cannot ordinarily be used to advantage in widening embankments.

Wheelbarrows. By this method the material excavated may be used to widen embankments, if conditions are favorable, and the cost is practically a constant to which a uniform addition is made varying directly with the length of haul. For fair dig-

ging it will be noted that casting is cheaper than any wheelbarrow work, and that casting with one platform is about the same cost as wheeling 125 ft. with wheelbarrows. If the material is merely to be carried across three or more tracks, where the traffic is so heavy that it is not desirable to lay gangways across the tracks, on account of safety, very fair results can be obtained by constructing boxes with two handles, similar to the handles on push or hand cars, on each end, and have two men carry each box across. This method, however, is more expensive than wheeling.

Push Cars. As it is necessary to protect push car work by flagmen, the greatest economy by this method will be obtained by working as many men with two flagmen as can be worked to advantage. This is indicated by the three dotted lines showing 4, 10 and 16 men actually ditching under the protection of two flagmen. It is here assumed that 20% of the time is lost on account of the traffic, but that this 20% covers the time spent in trimming up the cut. On the diagram, the three dotted lines indicate cost per yard if the men shovel the material off the car; while the three full lines indicate the cost if the car is so arranged that the material can be dumped, by placing an entirely separate box, open at one side, on the bed of the car, or some other suitable method. By such an arrangement, the cost per yard can be reduced some 3 to 4½ ct. over shoveling the material off the cars.

Work Trains and Hand Loading. The diagram is plainly marked showing the method covered by each line, and it is only necessary to call attention to the fact that where only 60 cu. yd. are handled per trip, the lines are dotted lines, and full lines are used where 120 cu. yd. are handled per trip. In all cases with work train (except one) it is assumed that all the men employed go with the train to unload, and for this reason the cost with 50 men, handling 120 yd. per train, becomes less than with 100 men under the same conditions, after a haul of about 2,600 ft., or ½ mile has been reached. If, however, the work is properly handled the whole number of men employed (where such large numbers are used) are not sent with the train, but are kept at work at the ends of the cut ditching with wheelbarrows, or possibly casting the material, where such can be done by the use of a platform, while part of the men unload. The cost will thus be reduced considerably, it being possible, by proper arrangements, to reduce the cost to almost what machine ditchers will accomplish.

A portable platform for carrying on the work trains for use in cases where material can be thrown out of the cuts by two

castings, consists of two posts 2 x 6 in., 12 ft. long, with two horizontal pieces 2 x 6 in., 10 ft. long, running into the bank to support the platform of five boards 1 x 12 in., 5 ft. long. The posts and horizontal supports are bored at intervals to permit adjustment of the height of platform. In a deep cut, a second scaffold may be placed above the first. This device was first furnished section foremen on the Southern Railway by Mr. W. A. Ford, Supervisor, but was found to be of such value as a time saver when trains were late, that ditching trains were equipped with them. One man on the scaffold can handle about as much dirt as two men can handle in the ditch.

On this diagram the question of using two or more work trains with a gang of say 100 men loading, the unloading being done at a distant point by plow and cable, has not been considered, as work of such character would vary to such an extent with the local conditions, that it would necessarily have to be considered specially for each individual case. It may be mentioned, however, that 100 men could load 1,000 cu. yd. of material already loosened and placed conveniently for loading, in four hours' actual working time and at that rate the total cost for one train amounting to say $22 per day, would be but 2.2 ct. per cu. yd. In order, therefore, to keep such a gang busy, a sufficient number of trains should be used, if conditions, such as traffic, side track facilities, etc., will permit. The whole question with work trains, therefore, resolves itself into equalizing the number and disposition of men employed, with the train service in such a way that one will not overbalance the other, and both will be in accordance with the requirements in regard to length of haul, traffic conditions, etc.

Machine Ditchers. These may be divided into two general classes: (1) Ditchers which load a scoop on one or both sides and then run to the end of the cut to dump the material, and (2) those which load a full train of material and unload by plow or by hand. The first kind can be used to advantage only where the haul is comparatively short, while the second class is economical for a long haul.

The requirements of a suitable machine ditcher of either class are that it shall be able to cut the full depth necessary, and close up to the ends of the ties in order to obtain a standard section; that it shall be quickly handled with the least number of men practicable; that it shall have the fewest possible parts likely to get out of order, and that it shall be capable of sloping the banks in fair shape either by a slope board or dipper under control of the engineman, the slope board probably being desirable even with the dipper. With either class of machine, the dipper

or scoop should be as large as can be handled to advantage in order to reduce the cost per yard, machines of first class having very long scoops, while those of the second class have dippers somewhat similar to a steam shovel dipper of about ¾ to 1 cu. yd. capacity. As in the case of steam shovel work, the engineman or the man in charge of handling the scoop or dipper, should be thoroughly competent, as the cost per yard of material will be greatly increased if the shovel work is handled slowly.

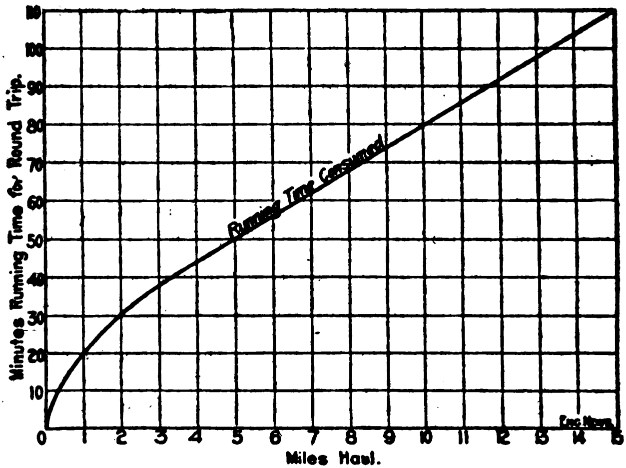


Fig. 19. Diagram of Estimated Time for Work Train to Make Round Trip to and from Place of Unloading; Exclusive of Time Consumed in Unloading.

Filling and Tamping a Viaduct Embankment. *Engineering News*, Nov. 5, 1914, gives the following:

The New York Connecting R. R. is carried over a part of Astoria, L. I., N. Y., by a viaduct constructed of earth filled and tamped between concrete retaining walls. These walls are held together by steel tie rods. These rods are encased in concrete as rapidly as the earth fill reaches them, which delays the work of filling and tamping somewhat.

The filling material is composed of sand, gravel and loam, excavated at Sunnyside yards by a 2½-cu. yd. steam shovel, and hauled 3.5 miles in 11-car trains by 18-ton dinkeys to the viaduct. Cars hold 3.8 yd. each, and 250 to 300 cars or about

1,045 cu. yd. are handled per day. The dumping track is carried by timber trusses resting on the concrete retaining walls. The steam shovel crew is composed of a steam shovel runner, a craneman, fireman, and 6 pitmen. Each of the 5 trains is manned by an engineman and brakeman. The dumping is done by a foreman and 5 laborers.

The earth after being dumped is spread in 12-in. layers and tamped with pneumatic tampers. These tampers are manufactured by the Ingersoll-Rand Co. and are of the "crown" model. Air for their operation is supplied by a compressor rated at 946 cu. ft. of free air per min., 100 lb. per sq. in. pressure, driven by a 150-hp. motor. Air is distributed through 3-in. and 2-in. pipe to distances of 1,400 and 2,100 ft. each way from the compressor. The average number of men employed in spreading and tamping is 45 laborers, 2 foremen, and 6 tampers. Two machinists are employed for ensuring the smooth operation of the tampers, 20 of which are on hand. With this crew of 51 men about 20 cu. yd. per man-day are spread and tamped.

The author would suggest that it would have been cheaper to spread the earth with a dragline scraper and puddle it with water.

Cost of Transporting Men, Tools and Supplies on Railroads for Grading. *Engineering and Contracting*, July 8, 1908, gives the following:

In carrying on construction work it is the custom of railroads to charge the construction certain rates of fares on the men employed, and freight on tools and supplies. This charge against the new work is credited to the operating department.

The following figures have been used by H. P. Gillette in estimating the cost of railroad construction. The figures of work done, and men, horses and tools and supplies needed are based on large jobs of construction, and are safe averages. The fares for men and the freight rates are those ordinarily charged by railroads to themselves and to one another.

One horse plus 1½ men readily excavate and move 15 cu. yd. of earth per day. Hence allow 360 cu. yd. per month per horse and 250 cu. yd. per month per man.

One man requires transportation at 1 ct. per mile, and freight on 200 lb. of bedding, cooking utensils, tents, small tools, etc. Hence for 100 miles transportation each way, or 200 miles round trip, we have

200 pasenger miles at 1 ct.	$2.00
1/10 ton bedding, etc., 200 miles at ½ ct. per ton mile..	.10
Total	$2.10

Since one man will excavate 250 cu. yd. per month, it costs \$2.10 divided by 250, or 0.8 ct. per cu. yd., if the job lasts only one month; but if the job lasts four months it costs 0.8 ct. divided by four, or 0.2 ct. per cu. yd., because in that time a man will move four times 250 cu. yd., or 1,000 cu. yd., and will only require transportation once at a cost of \$2.10. Other months are in proportion. For any other haul than 100 miles multiply accordingly.

Each horse requires the following equipment:

	Lb.
½ wheel scraper, at 500 lb.	250
½ wagon, at 2,000 lb.	1,000
Tents, harness, etc.	250
Total	1,500

Allowing 16 horses per car of 24,000 lbs., each horse stands for freight equivalent to 1,500 lb., hence:

	Lb.
Equipment for each horse	1,500
Weight of horse	1,500
Total, 1½ tons or	3,000

For each 100 miles of haul we have, therefore, 200 miles round trip; hence 200 miles × 1½ tone × 0.4 ct.= \$1.20.

Since each horse moves 360 cu. yd. per month, we have \$1.20 ÷ 360, or 0.3 ct. per cu. yd., if the job lasts only one month. But if the job lasts four months we have ¼ of 0.3 ct., or 0.075 ct. per cu. yd. Other lengths of time and other hauls are in proportion.

Each horse consumes ½ ton of food per month; hence if food is hauled 100 miles we have ½ ton × 100 miles × 0.4 ct.= 20 ct.

Since the horse moves 360 cu. yd. per month, we have 20 ct. ÷ 360, or 0.05 ct. per cu. yd. for each 100 miles of haul.

Summing up, we have the following costs:

	Cost per cu. yd. for transportation 100 miles and return.			
Duration of Work	Men Ct.	Horses Ct.	Food Ct.	Total Ct.
1 mo.	0.80	0.30	0.05	1.15
4 mo.	0.20	0.08	0.05	0.33
6 mo.	0.13	0.05	0.05	0.23
8 mo.	0.10	0.04	0.05	0.19
12 mo.	0.07	0.03	0.05	0.15

Note.—If the haul is 300 miles, multiply by 3. If the haul is 500 miles, multiply by 5. If the haul is 1,000 miles, multiply by 10.

The above is for work done by wheel scrapers and wagons and carts, but for steam shovel work the following would be the approximate cost for transportation:

	Tons
1 shovel	70
60 dump cars	120
Rail	65
Cross ties (6. in. x 6 in. x 6 ft.)	75
Three small locomotives	35
Pumps, drills, etc.	35
Total	400

400 tons × 100 miles × 0.4 ct. = $160.

Such a shovel as this will average at least 20,000 cu. yd. per month, hence we have $160 ÷ 20,000, or 0.8 ct. per cu. yd. for transporting the shovel 100 miles. This is equivalent to 1.6 ct. for transporting the shovel the round trip of 200 miles, when the job lasts only one month. For four months the cost would be ¼ of 1.6 ct., or 0.4 ct. per cu. yd. Other months would be correspondingly in proportion.

Such a shovel does not consume more than 60 tons of fuel and supplies per month; hence we have 60 tons × 100 miles × 0.4 ct. = $24. Since with this 60 tons of fuel there are 20,000 cu. yd. excavated, we have $24 ÷ 20,000, or 0.12 ct. per cu. yd. With such a shovel there will never be more than 40 men engaged in operating the shovel, operating the dump cars and trains, as well as in making temporary roadways and repairing equipment; hence each of these 40 men averages 500 cu. yd. per month, which is double the output where men are working with wheel scrapers, carts, etc., as above given; therefore the cost of transporting men per cu. yd. on shovel work is approximately one-half the amount given in the previous table.

Summarizing we have the following:

	Cost per cu. yd. for transportation 100 miles and return.			
Duration of Work	Shovel Ct.	Men Ct.	Fuel Ct.	Total Ct.
1 mo.	1.60	0.40	0.12	2.12
4 mo.	0.40	0.10	0.12	0.62
6 mo.	0.26	0.07	0.12	0.45
12 mo.	0.13	0.03	0.12	0.28

The above is for a haul of 100 miles, and for any other hauls multiply according to the length of haul.

If the workmen are of a restless disposition, and remain only a short time on the job before quitting, the cost of their transportation varies not with the length of the job but with the average time they remain on it. When they quit, of course their return fare is not paid.

Cost of Railway Grading by Steam Shovel. D. A. Wallace, in *Engineering and Contracting*, July 27, 1910, gives a description of the methods and costs of steam shovel work, loading slag, earth and sand into cars for railway ballasting and grading.

Slag for Ballasting. This slag was loaded by a 45-ton shovel working against a 20-ft. face, into cars placed on a spur track on a 3% grade. The grade permitted the spotting of cars by hand while the engine was unloading the loaded cars. The greatest haul was 4 miles. There was no delay to the slag train due to meeting revenue trains. The slag was in alternate vitrified and spongy layers. The use of the light shovel necessitated some use of powder but not more than the ground gang could drill the necessary holes for and handle. Holes were drilled on an average 9 ft. horizontally into the face 3 ft. from the ground line and about 10 ft. centers. Rodgers ballast cars were used. The size of the slag permitted easy unloading. The train crew with the help of one of the gang did the unloading and sweeping off. The wages were as follows:

Engineman, per month	$125.00
Craneman, per month	90.00
Fireman, per month	60.00
Foreman, per month	65.00
Ground hands, per day	1.25

The daily expense was as follows:

Engineman	$ 4.80
Craneman	3.46
Fireman	2.31
Foreman	2.50
6 ground men	7.50
2 tons coal at $2	4.00
Waste and oil	0.50
Dynamite	0.93
Work train	25.00
Total per day	$51.00

The slag cost $2 per car load of 40 cu. yd. or 5 ct. per cu. yd. Including this, the cost of loading, hauling and unloading was as follows per cubic yard:

6 cars, 240 cu. yd.	$0.262
7 cars, 280 cu. yd.	0.232
8 cars, 320 cu. yd.	0.209
9 cars, 360 cu. yd.	0.191
12 cars, 480 cu. yd.	0.156

Earth for Grade Raising. Loose earth was loaded into Hart convertible cars spotted on the main line. The shovel was cut in on both sides of the main line and cuts were widened. A 12-ft. face was worked. The dirt was unloaded by the railway company in widening fills or grade raising, as was most convenient, depending on the progress of the gangs and the time of revenue trains. The contractor was paid 7 ct. per cu. yd. pit measure for dirt loaded on cars. The following costs were for loading alone. The shovel used was a 70-ton Giant with a 2-cu. yd. dipper. The wages paid were as follows:

Engineman, per month	$150.00
Craneman, per month	90.00
Foreman, per day	2.00
Groundmen, per day (6 worked)	1.50
Watchman, per day	1.85

About 1½ gal. of cylinder oil at 40 ct. per gallon were used per day and 2 gal. of black oil at 10 ct. per gallon. The daily expenses were as follows:

Engineman	$ 6.00
Craneman	3.60
Fireman	2.00
Watchman	1.85
Ground hands	9.00
Total labor	$22.45
Cylinder oil	$ 0.60
Black oil	0.20
Waste	0.10
1 ton coal	1.50
Total per day	$24.85

The shovel loaded 45 cars of 24 cu. yd. per car or 600 cu. yd. per day.

Sand for Ballast. Two sand pits were opened up, one on each side of the main line, and the lead track to each pit was used as a loading track. A 60-ton Marion shovel was cut into one pit and a 45-ton Vulcan shovel into the other pit. Three work trains were used for spotting cars, hauling and unloading. Each crew handled different parts of the work depending on the arrival of the unloading trains and the speed of loading. One crew usually spotted cars for both shovels. This was done very easily because of the frequent moves of the shovels due to the shallow face of the cut. The sand was a white sand containing about 20% loam. It made a very satisfactory ballast for light traffic. Hart convertible cars were used and were unloaded by a Lidgerwood plow on new track. A large amount of time was lost due to the slow running necessitated by the very rough track.

The 60-ton Marion shovel, working 21 days in July, loaded 1,075 cars with 29,008 cu. yd.

The number of days worked was 22 or 223 hours, during which time there were 91 hr. 45 min. delays distributed as follows:

Cause.	Hr.
Moving shovel	23.9
Waiting for cars	53.2
Closing car doors	4.6
Coal and water	5.8
Derailments	3.3
Shovel repairs	0.9
Total	91.7

The 45-ton Vulcan shovel working 7 days in July loaded 235 cars with 7,570 cu. yd.

The number of days worked was 7, or 70 hr., during which time the delays amounted to 49 hr. 43 min. distributed as follows:

Cause.	Hr.
Moving shovel	7.1
Waiting for cars	28.3
Tank repairs	7.0
Shovel repairs	7.0
Derailments	0.3
Total	49.7

The total yardage loaded by both shovels was 36,578 cu. yd. The cost of loading, transporting and placing this yardage in the track was as follows per cu. yd.

Loading	$0.040
Transporting	0.074
Surfacing	0.231
Fuel and supplies	0.064
Rental equipment	0.069
Supervision	0.025
Total	$0.503

The face worked averaged 8 ft. and the haul was 10 miles.

In August the two shovels worked more nearly the same amount of time. The total working time of the 60-ton shovel was 26 days or 310 hours, during which time there were the following delays:

60-Ton Marion	Hr.
Moving shovel	43.0
Waiting for cars	82.5
Waiting for laborers	29.0
Waiting on track work	6.4
Miscellaneous	10.0
Total	170.9

45-Ton Vulcan	Hr.
Moving shovel	35.0
Waiting for cars	45.5
Waiting for laborers	20.0
Waiting on track work	15.0
Waiting for power	20.0
Repairing shovel	27.0
Miscellaneous	12.0
Total	174.5

Summarizing the work of the two shovels we have:

	60-Ton	45-Ton
No. cars loaded	1,268	1,046
No. cu. yd. loaded	33,486	30,710
Av. cu. yd. per day	1,272	1,121
Av. cars per day	48 4/5	40
Av. cu. yd. per car	26½	28⅔

The total yardage for the month for both shovels was 63,196 cu. yd. The cost of loading, transporting and placing this yardage in the track was as follows:

Loading	$0.019
Transporting	0.046
Surfacing	0.150
Fuel and supplies	0.075
Rental equipment	0.054
Supervision	0.019
Total	$0.363

Cost of Raising a Railway Embankment. Work on the St. Louis and San Francisco R. R. through the Alabopolya Swamp in La. is described in *Engineering and Contracting*, July 13, 1910.

The material in the embankment was the black gumbo commonly encountered in Southern Louisiana swamps. The work described consisted of raising the embankment and filling in the temporary trestling. The conditions were difficult.

The track was laid following closely behind the trestle gang, and frequent use of the track by the bridge material train put the track in very poor condition. A great portion of the embankment built by "station work" was partially washed out by high water, leaving holes 4 ft. deep for 15 or 20 ft. of track. The temporary trestles stood 12 or 18 in. higher than the approaches. This condition was due to the excessive settlement of the swamp soil and also to heavy rains. The worst holes were cribbed up with ties and tree branches, but even then a great amount of delay was caused the unloading trains by derailment and trains breaking in two in attempting to get over the bad places. It was necessary to unload dirt at these places before the track could be surfaced, as the gumbo would not hold a surface under one trainload of dirt. In many instances cars were unloaded standing on track 18 in. out of level and 3 ft. out of surface in a distance of 10 ft. along the rail.

Hart convertible cars were used and were unloaded by a Lidgerwood plow. Before dirt was unloaded on the fills it was necessary to jack the track up out of the gumbo. It was impossible to move the track with No. 6 Barrett jacks after the dirt was unloaded. In many instances it was found necessary to strip out the track before it could be lifted from the gumbo with 12 No. 6 Barret jacks, resting on boards, per rail length. The grade on embankment was raised not less than 12 in. at any point.

The unloading was planned so that when the first gangs were unable to get the track in shape ahead of the unloading or when they were not able to care for the dirt as fast as it came, the unloading was done on the trestles, and as they were being filled

a gang was kept busy tamping the dirt in under the caps and stringers. Following a rain, the dirt packed hard and the cars and stringers were removed by the Lidgerwood and cable.

The shovel pits from which the dirt for filling was got, averaged a 15-ft. face and 1,600 ft. in length. The dirt was a sandy clay compacting very quickly in embankment. The pit was opened up along one side of the main line and track laid behind the shovel in the first cut and used as a loading track for the next cut of the shovel. More difficulty than usual was experienced in keeping the pit properly drained. Good drainage was very necessary to take care of the frequent and heavy rains common to the country. Three trains were used, 1 loading train, which handled the water cars for the shovel, 1 swing train which made the run of 12 miles to the front in 40 minutes and 1 unloading train. The unloading was started 12 miles from the pit. A siding and water tank were located there affording water to the swing and unloading trains. About 25 minutes were generally consumed there in switching empties and locals.

The work recorded was done from Sept. 12 to Oct. 16, 1907. The daily expenses were as follows:

Loading, Transporting and Unloading:	
1 teamster at $150 per mo.	$ 5.00
3 conductors at $100 per mo.	10.00
3 brakemen at $75 per mo.	7.50
3 brakemen at $60 per mo.	6.00
3 enginemen at $100 per mo.	10.00
3 firemen at $75 per mo.	7.50
3 engine watchmen at $60 per mo.	6.00
1 hostler at $75 per mo.	2.50
1 hostler helper at $1.80 per day	1.80
1 steamshovel engineman at $150 per mo.	5.00
1 steamshovel craneman at $90 per mo.	3.00
1 steamshovel fireman at $75 per mo.	2.50
1 steamshovel watchman at $60 per mo.	2.00
1 machinist at $0.35 per hour	3.50
1 machinist helper at $1.80 per day	1.80
1 blacksmith at $0.35 per hour	3.50
1 blacksmith helper at $0.20 per hour	2.00
1 car repairer at $0.25 per hour	2.50
1 car repairer at $0.275 per hour	2.25
1 carpenter at $0.275 per hour	2.75
1 pumper at $60 per mo.	2.00
1 Lidgerwood engineer at $90 per mo.	3.00
6 pit men at $2 per day	12.00
6 cablemen at $2 per day	12.00
Total wages	$116.10
20 tons coal at $4	$ 80.00
Supplies	2.56
Ice	1.00
Water at 50 ct. per tank from city	2.00
10 gal. gasoline at 10 ct.	1.00
Total supplies	$ 86.56

1 steam shovel rent	$ 10.00
3 engines rent at $1.53 per day	16.59
62 cars rent at 50 ct. per day	31.00
1 water car rent at 50 ct. per day	0.50
1 spreader rent at $2 per day	2.00
1 Lidgerwood rent at $5 per day	5.00
Total plant rental	$ 65.09
Add 10% super. and 5% misc.	$ 40.15
Grand total	$307.90

Note.— The 5% misc. includes overtime, etc.

A total of 2,060 cars, or 60,180 cu. yd., were handled in 30 working days, 2 of which were spent in moving. This is at the rate of 2,000 cu. yd. per day, at a cost of 15.4 ct. per cu. yd.

Comparative Costs with Flat Cars and Large Dump Cars. John W. King, in *Engineering and Contracting,* May 17, 1911, describes the building of a 95-ft. fill, ¾ mile long, for the Union Pacific Railroad across the Papio Valley. The earth was hauled from a cut a little over 2 miles away, of almost the same depth as the fill, but considerably shorter. To construct this fill a timber trestle was erected to the full height for the entire length, the bents being set upon piles driven about 20 ft. into the soft gumbo to clay. Trains were brought over a temporary track, backed out on the trestle and there discharged, filling the trestle to the height of about 30 ft., 500 ft. in advance of a second layer, 20 ft. high, which was followed by a final layer, 15 ft. high. The stepping off of the fill in this way was supposed to impose the load upon the soil gradually, its weight squeezing the water out of the soft soil, allowing it to solidify before applying a greater load. The weight of the trestle and equipment were presumably carried by the piles. The fill had been raised this way until the last layer had been nearly finished, when without warning the valley floor upheaved, and the earth fill settled down in places many feet. The trestle was thrown badly out of line and level and condemned as unsafe for further use. Soundings had been taken by the railroad company and the contractor had accepted the work with full knowledge of the borings. He considered the subsoil sufficiently strong to support the superimposed load, with the feeling that a slip, should one occur, would be but surface dislodgment. The slip that did occur (shown in Fig. 1), however, had a much more far reaching effect, that might have been avoided had the contractor realized the situation and provided for this contingency in the beginning. Previous to the upheaval the contractor had been working a plant consisting of the following:

2 (70-ton) shovels
48 (30-ton) flat cars

2 (60-ton) road locos., separate tender, switching type
3 (30-ton) saddle tank dinkeys
1 Lidgerwood unloader plow
1 hoisting engine.

This plant, working double shift, 20 hr. per day, excavated 5,890 cu. yd., place measure. The cost of direct operation per cu. yd. not including plant or overhead expenses, but only the direct labor, was about 5.56 ct. per cu. yd. After the destruction of the trestle the old plant was removed from the work and a new plant substituted. This consisted of the following:

1 (90-ton) shovel
8 Lawson 33-yd. dump cars
2 road locomotives, as before.

From actual timing on the trestle, 4 of these Lawson cars were dumped, replaced, and started on the return to the gravel pit within 5 min., or at the rate of 1.25 min. per car, which for a 5-car train would require 6.25 min. at the dump.

With the new plant eleven units, working double shift of 20 hr. per day, excavated 4,800 cu. yd. place measure, at a cost for direct operation of 3.45 ct. per cu. yd. Thus 11 plant units with the new method, as against 57 by the former methods, using but 40 men instead of 100, did the work for 62% of what it had formerly cost.

Manner of Filling a 75-Ft. Trestle. When the Spokane, Portland and Seattle Railroad was built in 1907, Sprague Gulch was crossed on a trestle in order to expedite the work. This trestle is 4,869 ft. long with a maximum height from base of rail to surface of water of 101 ft., and average height of over 75 ft. It is composed of 317 six-post bents, 56 of which rest on piles.

The advantageous location of a borrow pit made it possible to fill this trestle at a less cost than that of replacement with a steel structure. Advantage was taken of the sloping bank on the east side of the gulch to open borrow pits on each side of the track at levels of the various lifts, thus avoiding crossing under the trestle and eliminating uphill haul. Borrow pits totaling 180 acres were purchased, the material obtained being glacial drift of gravel and boulders.

The contractor provided two complete outfits, consisting of two 70-ton Bucyrus shovels, with 8 dinkey engines and 116 four-yard cars, to handle the work, and to comply with the specifications, which required that the fills on each side of the main trestle be brought up together to avoid unequal pressures tending to force the structure out of line, it was decided to build the fill in three lifts, as shown in Fig. 20, the first one approximately 35 ft. high and the other two 30 ft. each. It was planned to carry these lifts

across the entire length of the fill, making the first lift across the bottom of the gulch about 1,800 ft. long. However, the contractor found such good material in uncovering his first cut that he raised his grade gradually as he extended the fill across the gulch and made a first lift entirely across the bottom.

The specifications also required that the contractor build his construction trestles as close to the main trestle as practicable, and fill out from these so that if there should be any tendency for the ground to rise beyond the slope, it would not interfere with the alignment of the high trestle. The wisdom of this provision became evident when such a movement appeared at one point without any damage to the trestle. At this point the ground raised 5 ft. for a strip about 140 ft. long by 50 ft. wide, about two months after the work started. Since that time no further movement has been noted.

From the section shown it will be noted that different layers

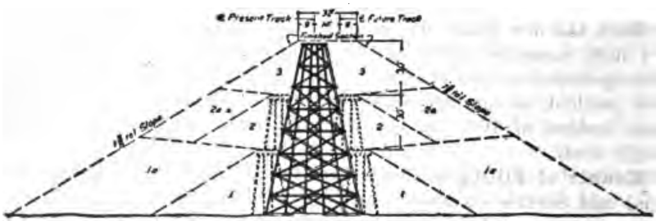


Fig. 20. Manner of Filling High Trestle.

are sloped slightly in towards the center, so that should there be any tendency for the material in the bank to slide it will move towards the center and compact. As fast as the fill is completed as far as it can be reached from the trestle, the tracks are thrown on the fill and banks widened out to the slope stakes before a second lift is started. When the first lift was entirely completed the shovels were moved up the slope of the borrow pit to the level of the second lift, this change causing an interruption to the work of but five hours.

Work was started on March 15, and the first lift completed on August 23. Up to October 31, 1,116,505 cu. yd. of material had been moved. This amounts to 65,200 cu. yd. per month per shovel. The contractor's force averaged about 150 men.

For filling the third lift the contractor changed from narrow gage to standard gage equipment, unloading from the main line under control of a regular train dispatcher.

Drag and Wheel Scraper Work in North Carolina. The meth-

ods and costs of constructing 24 miles of the Watauga and Yadkin Valley R. R. in North Carolina are given by H. C. Landon in *Engineering and Contracting,* Apr. 1, 1914. Approximately 24 miles were graded by company forces. The yardage removed was 475,052 of which 99,688 cu. yd. were rock. The labor cost, including explosives, was approximately 12 ct. per cu. yd. for earth and 36 ct. per cu. yd. for rock. The powder used amounted to 213,250 lb. and the dynamite to 24,000 lb. It is estimated that the powder threw off the grade, so that no further handling was necessary, at least 80,000 cu. yd. An additional large yardage of material was shaken up to be loaded by wheelers or loaded into the carts or cars. The methods and costs of the rock excavation are described in my "Handbook of Rock Excavation."

Almost all the work was done by company forces under the direction of the chief engineer. One small six-mile section was constructed by contract. Mr. Landon says that it was believed by the organization that the road could be built with greater speed by company forces than by contract and with less annoyance, as it was known that numerous changes of alignment would necessarily be made. He states that it is probable that the greater portion of the balance of the line would be constructed by contract.

The first 30 miles of line was, in general, light work. There were some heavy cuts and fills but it was not practicable, on account of poor roads and lack of bridges, to entertain any steam shovel proposition, and generally the cut and fills were too light to make steam shovel operation economical. Labor was very scarce and it was planned to do the work with the aid of teams, machines and powder as far as practicable.

After a careful study of the profile it was decided to purchase the following equipment:

12 (1½-cu. yd.) Troy wagons at $112.50	$1,350.00
24 drag scrapers at $5.56	133.44
36 No. 2½ wheel scrapers at $36.75	1,323.00
1 elevating grader	920.00
4 (2,500-lb.) wagons at $55.00	220.00
8 (16-ft. x 24-ft.) tents at $38.63	309.04
2 (32½-ft. x 65-ft.) mule tents at $149.30	298.60
2 Ingersoll rock drills at $312.50	625.00
1 (16-hp.) boiler on wheels, 2nd hand	300.00
10 (1-yd.) dump carts with harness at $46.00	460.00
4 (2-yd.) dump cars with harness at $30.00	120.00
100 steel wheelbarrows, 3 and 4 cu. ft. at $3.00	300.00
12 doz. round point D handle shovels at $5.25	63.00
4 blacksmith outfits, including a forge, anvil, and other tools at $40.00	160.00
12 doz. picks with handles at $4.00	48.00
Total cost of equipment	$6,630.08

The dump wagons and grader were used only about two months, and did fair work in the territory where they were employed.

They were not used for a longer period on account of the inability to get sufficient mules and teams to operate them.

When the company started work they were advised that all the teams that would be required could be secured in the community, but although $3 per day, or 50 ct. more than the ruling price, was paid, only 15 to 18 teams, and they not of the best, could be secured. It was then decided to purchase mules, and 45 teams were bought. The average weight of these animals was over 1,255 lb. These teams were in almost continual daily service from August 1, 1912, to June, 1913. Only two mules were lost and it is estimated that there was not over 5% lost time from the mules in service. The cost of feeding the mules averaged 95 ct. per team per day. Hay averaged $25 per ton and oats 57.5 ct. per bushel delivered at the camp. The teams were well fed and were taken care of by a competent stable boss which accounts for the small percentage of loss in mules and in time.

Organization of Forces. The organizations of the various forces were fixed and were called "standard" and were only varied when it was shown that the needs of the work demanded it.

The "standard" wheel scraper force was as follows for hauls not exceeding 300 ft. Six wheel-scrapers with teams and drivers, two teams, two plows, one snatch team, one man dumping, one loader, one wheeler, one water boy when required and one foreman. When the haul increased, the number of wheel scrapers was increased in order to keep the snatch team and other laborers busy. This was very closely watched by the foremen of the various gangs in order to keep up their record, as every dumper was supplied with a counter and the day's work reported. In this way a very close estimate could be made of the yardage moved.

Drag Scraper Work. The "standard" drag scraper force consisted of six scrapers with teams and drivers, two teams to plow, one dumper, one loader, one foreman, and one water boy.

The drag scraper work and the wheel scraper work were watched with great care to determine the economical haul. The drag scraper is efficient for very short hauls. Observation of the various hauls up to 200 ft. fully demonstrated the fact that for a distance of over 100 ft. the drag scraper was an expensive implement. Under 100 ft. it would do efficient work. Wheel scrapers ordinarily could be used where the drags could be used, and had the advantage of making about the same speed with about five times the load. As a general rule only a few drags should be used on work of this kind. Their advantage is in their cheapness, and for a small amount of work for short hauls the drag scraper is desirable. A gang of wheel-barrow men properly han-

dled will do work about as cheaply as a drag, and in some instances at less expense.

Assuming the haul for drag scraper to be 100 ft., a lively mule team to a scraper will not make over 1.3 miles per hr. on account of the frequent turns in loading, or about 6,900 ft. per hour. This is at the rate of 3.45 cu. yd. per hour or 34.5 cu. yd. per 10-hr. day per team. With a "standard" drag scraper force, and teams at $3 per day, 8 drags will handle 27.6 cu. yd. each per 10-hr. day at a total labor cost of $37.50 or nearly 14 ct. per cu. yd. For a haul of from 50 to 75 ft. the cost will not exceed 12 ct. per cu. yd. About 75 ft. should be the maximum haul with drag scrapers. Six drag scrapers with a shorter haul were therefore established as the maximum to be used with the minimum haul. Actual observation of a 110-ft. haul with country teams indicated that under the best conditions only 25.5 trips were made per hr., or a speed of 83 ft. per min. The company teams, which were all well fed Missouri mules, made as high as 120 ft. per min. with drag scrapers on a haul of 150 ft. These results were obtained under the best possible conditions where the dumper man counted and reported every load and in addition the teams were under personal observation of the general manager.

A few drag scrapers on every job of similar character are a good investment but the number in use should be limited. An injudicious foreman will often use them at the company's expense.

Wheel Scraper Work. The "standard" wheel scraper forces, above given, were modified as the hauls increased, the number of wheelers increased to 8 and, possibly, with very long hauls, to 10 or even 12. In only one instance did the haul with wheelers much exceed 600 ft., and in this instance the haul averaged 1,350 ft.; ten wheelers only were available but they were able to handle 225 cu. yd. at a cost of 23.5 ct. per cu. yd., figuring teams at $3.50 per 10-hr. day, although all the teams which were actually used cost only $3 per day.

With a haul of 415 ft. a careful timing of the teams indicated that they were making 4 trips in 20 min. An average of twelve trips per hour was made for the entire day. The wheelers were loaded to their capacity and therefore an average of nearly 60 cu. yd. per wheeler was secured. The wheeler force using only 6 wheelers cost $30 per day. The labor cost in this case did not much exceed 10 ct. per cu. yd.

Wheel-Barrow Excavation. The wheel-barrow, when properly used, was a most useful, necessary, convenient, and economical tool. Three types of barrows were purchased: The ordinary railroad wooden barrow, the wooden frame contractor's barrow with steel tray, and the whole steel wheel-barrow with one-piece

tubular bent handles. Barrows of 3 and 4 cu. ft. capacity were bought; the barrow holding 4 cu. ft. in general seemed to suit the work and could be handled about as easily as the barrow holding only 3 cu. ft. The ordinary wooden barrow gave very poor service. A few of the barrows with wooden frames went out of service, but the whole steel wheel-barrows were practically as good as new after 8 months' fairly good service. The barrows were painted when out of service any length of time.

For side hill work and for open grade work the barrow gave very efficient service. Observations on side hill work showed that gangs of 25 men handled dirt at the rate of 8 wheel-barrows per min. for an hour with a haul of 21 ft. This would mean that they moved over 500 cu. yd. in wheel-barrows holding 4 cu. ft. Good runways were always provided so that the loads could be moved with the least possible waste of energy.

The gangs were placed in the hands of efficient foremen who taught the men how to handle the dirt with the least possible loss of time. At all times it was the endeavor to have a "standard gang" of not less than 25 men under each foreman. The work varied as the conditions necessitated. In some cases much drilling was required and in others, none at all.

Dump Car and Cart Excavation. Four small dump cars with revolving bodies were found to be convenient and useful in short cuts and at the approaches to the one tunnel that was built. These cars run on a track of 30-in. gage and had a capacity of 2 cu. yd. The cars were particularly useful in small cuts and where the haul was long. The revolving body would permit the car to be dumped in building the fill ahead of it or it could be dumped on the side to widen the fill or waste the material. Light rails not being available, these cars were run on a track made of 4 x 4 oak timbers. The wooden rails required only a few renewals during their six months' service.

Dump carts could be used economically only upon hauls about 100 ft. long, but two of the cars moved by mules could keep a gang of 10 to 12 shovellers continually busy where the haul was from 600 to 700 ft.

In one cut alone it is estimated that two of these cars handled 15,000 cu. yd. of earth and rock with a maximum haul of 650 ft. at a cost not to exceed 20 ct. per cu. yd. The average gang, including drillers, was about 14 men and a foreman. This number of men loaded about 150 cu. yd. per day at a labor cost of about $25 per day. It took nearly three months to remove the cut.

While dump carts could be used for the short hauls of 100 to 125 ft. efficiently, yet they were used to advantage where the maximum haul was 250 ft., provided the roadway was kept in

good order and several carts were used to keep a good sized gang moving. In one instance 6 carts were used in completing a fill and did the work very rapidly where the haul was approximately 150 ft. Six carts and 30 laborers moved 325 cu. yd. per day at an expense of approximately $47 or about 15 ct. per cu. yd. As a general rule the cost of handling earth and rock with dump carts and men was about 26 ct. per cu. yd., exclusive of the cost of explosives.

Methods of Using Explosives in Soft Ground. In using explosives it was difficult at first to get the desired results, as all the old time powder men believed in the single shot or two or three shot method rather than in the large blast. Moreover the experienced men that were employed had only used explosives to shatter and break up rock or very hard soil, so that it could be handled by either hand or steam shovels, and the old powder men at first tried to continue the use of that method, whereas, it was desired to throw as much of the earth and rock from the cuts as possible without resorting to further methods of removal.

In general, in earth or soft rock where the cut at the center line was over 4 ft., the first line of holes was placed not more than 2 ft. above the center line. All holes were driven to a point 2 ft. below grade and usually about the same distance apart as the depth of hole to grade, except when the depth was greater than 15 ft. The maximum distance apart was 15 ft. If the hillside was steep and the lower side of the road bed at grade, one set of holes was sufficient. If the cut under ordinary circumstances was a through cut with a depth of cut of 2 ft. or more on the lower side, then a lower set of holes was drilled parallel to the first at the lower ditch line at points midway between the upper holes, so that there would be no question of moving the material out of the way. This did not materially increase the amount of powder used as 1 cu. yd. of soft rock and earth was moved with about 2 lb. of powder. The soft rock usually was a decomposed granite or Carolina gneiss which was not hard to drill. The general tendency was to use too much powder. In putting down holes in earth and soft rock hand and churn drills were successfully used.

Bibliography. "Railroad Construction," Walter Loring Webb; "The Catskill Water Supply of New York City," Lazarus White; "Railway Estimates," F. Lavis.

"Relative Cost of Filling and Building Trestles," *Trans. Eng. Asso. of the South*, Vol. 12, 1901.

"Settlement of the Embankment Between Squantum and Moon Island, Boston Main Drainage Works," Henry N. Carter, *Jour. Asso. Eng. Soc.*, Vol. 11, 1892.

"Second Track Construction and Improvement of Line and Grade from Madison to Bariboo, Wisconsin, Chicago and North Western Ry.," H. W. Batten, *Engineering News*, June 3, 1897; "Method of Crossing Marshy Ground on the Detroit and Milwaukee Ry. in 1877," *Eng. News*, Nov. 21, 1901; "An Interesting Example of False Work Construction," J. F. Jackson, *Eng. News*, March 9, 1893; "Haslett Park Sink-Hole on the Grand Trunk Railroad," *Ry. and Eng. Review*, Dec. 31, 1904; Long Fill Built from Borrow.

CHAPTER XX

DESIGN AND CONSTRUCTION OF EARTH DAMS

Design of Earth Dams. H. A. Hageman in the *Stone and Webster Journal*, Feb., 1916, gives the following:

Earthen dams usually consist of

(1) A bank of earth containing homogeneous material throughout, or
(2) An embankment having a central core of masonry, concrete, or a puddle of selected impervious materials, or
(3) An embankment having a puddle or selected material on the water slope, or
(4) An embankment resting against an embankment of loose rock, or
(5) An embankment of earth, sand and gravel, sluiced into place by flowing water.

The plan of construction adopted is dependent upon conditions at the dam site, the materials available and the design of the structure.

Foundation. The dam site should be carefully selected and its location chosen only after the character of the foundation has been thoroughly examined by test borings.

It is important that the dam be constructed on a stratum that is impervious or nearly so, and that suitable cut-offs be provided to prevent harmful leakage through the structure.

The entire surface area within the confine of the dam should have all the undesirable material removed from the foundation.

The depth of the excavation is dependent on the character of the material encountered and the judgment of the engineers.

Any springs encountered should be diverted or drained.

Materials. The best results are obtained from a mixture containing 70 to 80% gravel, having sufficient variety of sizes and the balance of clay to completely fill the voids.

The use of clay alone or in large quantities is not recommended, as it swells when wet and shrinks in drying. The percentage of clay to be used in the dam varies from 15 to 30%, the amount being entirely dependent upon the nature of the material mixed with it.

That portion of the fill outside the puddled section should consist of sand, loam or fine gravel, carefully selected.

No material which is liable to disintegrate or which is soluble in water should be used.

It is desirable that a mechanical analysis should be made of the materials in the foundation of the dam and those of which

it is to be constructed; also that the rates of percolation of water through the materials should be determined.

Reference is given to the experiments of

1892 Report of Massachusetts State Board of Health.
North Dike of the Wachusett Reservoir, Clinton, Mass., by F. P. Stearns.
  Trans. A. S. C. E., Vol. XLVIII, pp. 259–277.
  Eng. News, May 8, 1902.
Cold Springs Dam
  Eng. News, March 7, 1907.
The Bohio Dam, Panama, by G. S. Morison
  Trans. A. S. C. E., Vol. XLVIII, with discussion by F. P. Stearns and others.

Design. The design of earthen dams should not be based upon mathematical calculations of equilibrium and safe pressure, as in the case of masonry dams, but rather upon results obtained from experience.

The important factors to be studied to determine the profile of a proposed earthen dam are:

(1) Selection of the dam site.
(2) Character of the foundation.
(3) Material available.
(4) Percolation factor of the material to be used in constructing the dam and that in the foundation.
(5) Location and kind of core wall, if necessary.
(6) Slope of upstream and downstream faces, including location and width of berms.
(7) Height of top above high water.
(8) Paving of slope above high water.
(9) Location and class of construction of spillway, outlet and waste pipes, etc.
(10) Placing of material. Hydraulic or dry fill.

Profile Dimensions. The dimensions usually adopted for the profile are as follows:

Top width, see formula below.
Superelevation above high water, 5 to 25 ft.
Upstream slope, not less than 3 to 1.
Downstream slope, not less than 2 to 1.

The following formula has been suggested for determining the top width.

$W = 1/5\,h + 5.$
$W =$ top width in feet.
$h =$ height of dam in feet.

The top of the dam should be beyond the reach of all waves and the following formula by Stephenson is commonly used for determining the height:

$X = 1.5\,F + (2.5 - \sqrt[4]{F})$
$X =$ Height in feet above high water elevation.
$F =$ Sweep of wind in miles in the longest straight line which can be drawn on the water surface of the reservoir.

The upstream slope is made flatter than the downstream slope for the reason that the natural slope of earth is less when wet than when dry.

The upstream slope should be paved with stone or concrete to protect the dam from wave action and burrowing animals.

The downstream slope should be paved or seeded.

Core Wall. The subject of the kind of core wall that should be provided for an earthen dam is a much disputed question.

When sufficient impervious material is obtainable to construct the entire structure, it is obvious that a core wall is unnecessary.

When a core wall is necessary the type to be used should be carefully considered.

English engineers are disposed to favor a puddle core wall, while American engineering practice inclines toward a masonry core wall, although many dams containing a puddle core wall have been built in this country.

The core wall should, if of concrete, always be well reinforced and constructed upon an impervious foundation and extend up to the high water elevation. It should be well supported on each side by the embankment, and carefully placed in such a manner as not to distort or break the wall during construction.

Puddle Core. The puddle core is usually less expensive than the masonry core. When properly constructed it is practically watertight and settlement of the embankment does not tend to rupture it. It also makes a better union with the rest of the embankment than the masonry core.

Undoubtedly the best material for a puddle core is a gravel containing just enough clay to bind the parts together and make them water-tight. When the material cannot be obtained in bulk, the component parts should be uniformly mixed dry, then wetted and worked to make a tough, elastic mass. The material should be deposited in thin layers and well rolled when sufficiently dry.

The dimensions for a puddle core wall:

Top and bottom thickness should in each included case be a matter of judgment with the engineer, whose decision with respect to the dimensions will be governed by the quality of the material available for the embankment.

Modern engineering practice suggests that dimensions less than the following should not be used.

Masonry Core. The chief objections to a masonry or concrete core wall are the danger of its having to withstand the total water pressure due to percolation from the reservoir through the upstream slope and to the probability of being cracked from temperature changes or from the settlement of the embankment.

Masonry core walls are usually from 2.5 to 6 ft. wide at the high water elevation and both surfaces are battered uniformly from the top to the natural ground surface and then are vertical to the foundation.

The thickness at the bottom of the batter should be from one-sixth to one-eighth of the head of water on the dam.

Placing the Embankment. When the material is not placed by the hydraulic process, it should be deposited in thin, level layers, wetted and rolled with a heavy power-driven roller. Before placing an additional layer of material, the last one should be wetted and harrowed to insure bonding with the next course.

The upstream side of the embankment should be kept higher than the downstream slope for drainage purposes.

The conditions best suited for an economical hydraulic fill are:

(1) An abundance of water at an elevation or pumped to form a sluicing head.

(2) An ample deposit of the materials for forming the dam, convenient to both ends and at an elevation to permit of the grades necessary to carry the material.

It is customary to deposit the coarser materials near the slopes and the finer materials toward the center.

The hydraulic sluicing method affords a safe and satisfactory method of constructing an earthen dam, since it segregates the puddle cores from all classes of soils and assembles them into a mass of marked uniformity.

By this method the structure does not require a core wall and a large proportion of the dam when made from proper materials becomes puddle clay.

The process has been used successfully in constructing many important embankments, and it has been suggested that it offers

a reasonable compromise between core walls of masonry and puddled clay.

When the materials which are to be used in constructing the dam have been fully analyzed mechanically and the percolation factor is known, the most impervious material is placed next to the water line, the least impervious material being placed on the downstream slope where it will give stability and drainage.

Slope Protection. The upstream slope above the low water line should be protected by a facing of rock paving. The stones should be laid on edge in a course of gravel. The least dimension of any stone should not be less than 8 in.

Below the water line the slope should be covered with loose rock. All voids between the stones should be filled with gravel.

The top of the embankment should be paved or sodded, as may be decided upon.

The downstream slope should be covered with loam and planted with a quick growing grass seed.

All berms should have paved drains.

Appurtenances for Dams. The waste water spillway is an essential part of the dam, and its location and construction should be carefully considered. Its location is somewhat dependable upon local conditions.

The spillway, together with its abutments and wing walls, should, where possible, be founded on rock and constructed entirely of masonry well anchored to the earth fill, with cut-off walls of such dimensions as will preclude all possibility of water passing under or around it.

The design should provide for a weir and wing walls of such dimensions that unusual floods can be easily discharged through the overflow waterway without coming in contact with or causing any damage to the earth embankment.

It is important that all conduits, whether of metal or masonry, that are built into the dam, shall be supported on an unyielding foundation.

Masonry cut-off walls should be built around the conduits at intervals, to prevent water leakage between the conduit and the earth fill.

Permeability of Concrete and Puddle Walls in Earth Dams is discussed by W. D'Rohan in *Engineering and Contracting*, January 18, 1911. He draws a comparison between conditions found by a board of engineers who were consulted as to the safety of the new Croton Dam and conditions found in the north and south dikes of the Wachusett dam. The proposed extension of the new Croton Dam was to be of earth with a masonry core wall of over 180 ft. in height. Under their direction, borings were made in

several earthen dams with concrete and masonry core walls at right angles to the axis, and at such intervals as to show that in almost every case there was a continuous water plane extending from the water surface of the reservoir to the core wall, and on the downstream side to the lower toe having a maximum inclination of 20%, thus showing that the cores were not water tight and not effective in preventing water from passing through the dam, as the dams were saturated below this plane. While this seepage may be low and have no power to remove any particles of the dam, nevertheless, it is a source of danger and the recommendation of the Board to substitute a masonry dam was immediately adopted.

The puddle core built in the north and south dikes of the Wachusett dam consisted of 6-in. layers of fine loam soil, well sprinkled and rolled. Recent experiments to determine the permeability of this type of earth or loam core in an earth dam have been made by means of a series of pipes driven into the embankments of the Wachusett dikes. The results as reported indicate that while the plane of saturation on the reservoir side of the loam core was level with the water in the reservoir, it dropped immediately below this core to a level slightly above the base of the dam. Weekly measurements proved that the amount of water draining out of the dike was not in excess of what might be expected, as the natural drainage from precipitation on the area of the dike itself. No masonry or concrete core-wall ever built in an earth dam can show better results than these, and few can compare with them in the absence of percolation from the reservoir.

Concrete Core Walls are used in India as protection against burrowing animals only. Puddling clay is scarce and dams are made a homogeneous whole to prevent percolation. For protection from burrowing animals, a 6-in. layer of broken stones on the lower slope has been found sufficient in English and Indian dams.

The San Leandro Dam. Burr Bassell in *Engineering News*, Sept. 11, 1902, gives the following:

The San Leandro dam, of the Oakland Waterworks, Calif., was commenced in 1874, and construction was continued without interruption until the latter part of 1875, when a height of 115 ft. above the bed of the creek had been attained.

A general plan and a cross-section of the dam are shown in Fig. 1. The crest of the dam is now 500 ft. long and 28 ft. wide. The original width of the ravine at the base was 66 ft. The length of the axis of the base from toe to toe of slopes is now 1,700 ft. The toe of the lower slope is 121 ft. below the high

water surface of the reservoir. A puddle-filled trench was carried down 30 ft. beneath the original surface, reaching rock, except at the east end, where 20 to 30 ft. of solid clay was penetrated.

It was the original intention of the company to raise the dam 10 ft. every 4 or 5 years until it was 50 ft. higher than it is today, or to a height of 175 ft. above the bed of the creek, and in order to do this safely, the base of the dam was extended to the dimensions shown by the sketches. All that portion of the dam within a slope of 1 on 2½ at the rear and 1 on 3 at the face,

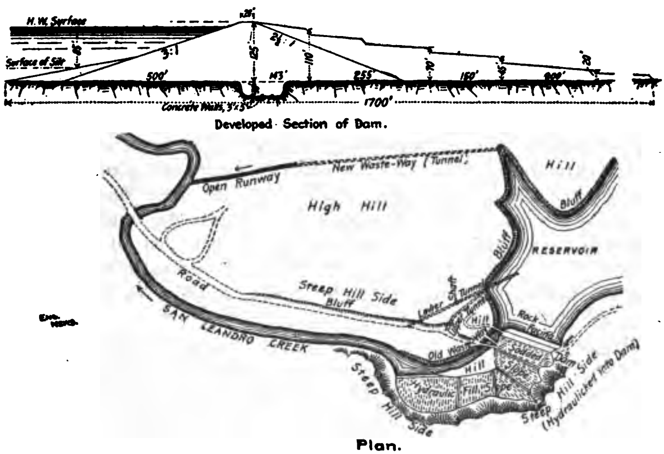


Fig. 1. Plan and Cross Section of the San Leandro Earth Dam.

is built of choice material, carefully selected and put in with great care. The portion outside of the 1 on 2½ slope-line at the downstream side of the dam, was sluiced in from the adjacent hills regardless of its character, and is of ordinary soil with more or less rock.

This process of sluicing was to be carried on during the winter months, by gravity flow, when there was an abundance of water, until eventually it would fill the canyon below the dam. This would give an average slope of 1 on 6.7 at the rear. It was thought that the location was particularly favorable for this kind of construction, the original intention being to raise the dam from time to time, as already stated, not only to increase the storage as the demand for water increased, but to meet the an-

nual loss in capacity caused by the silting up of the reservoir basin. I understand that this deposit has averaged about 1 ft. in depth per annum.

Some material was also sluiced in on the front, or wet slope, for the reason stated by Mr. Boardman, as follows:

The rocky ridge through which the upper and lower tunnels are driven is of a broken formation, some of it very hard and other portions soft, more or less broken and full of seams, and we discovered water percolating through the seams into the tunnels. It was impossible to get at the face of the slope, or find the seams, as the reservoir was full, and had it been empty we could not have found them. The only practical way was to sluice in fine clay on the face of the slope, which, under the action of the water, closed up the seams and stopped the seepage.

Under the main body of the dam the surface was stripped of all sediment, sand, gravel and vegetable matter. Choice material, carefully selected, was then brought in by carts and wagons and evenly distributed over the surface in layers about 1 ft. or less in thickness. This was sprinkled with just enough water to make it pack well, not enough to make it like mud.

During construction a band of horses was led by a boy on horseback over the entire work, to compact the materials and assist in making the dam one homogeneous mass. No rollers were used on this dam.

The central trench was cut 30 ft. below the original creek bed. In the bottom of this trench three secondary trenches, 3 ft. wide by 3 ft. deep, were made and filled with concrete. These concrete walls were carried up 2 ft. above the general floor of the trench to break the continuity of its surface.

The Ashokan Reservoir. *Engineering and Contracting* Oct. 19, 1910, gives the following:

The Ashokan Reservoir is formed by a masonry dam with earth wings across Esopus Creek, and a long earth dike across the valley of the Beaver Kill, in the Catskill Mts., N. Y. The extent of these dams is shown in Fig. 2.

Some of the construction quantities involved were:

Earth excavation, cu. yds	2,055,000
Rock excavation, cu. yds	425,000
Earth and rock embankment, cu. yds	7,265,000
Portland cement, bbls	1,100,000
Concrete masonry, cu. yds	882,000
Paving and riprap, cu. yds	105,000
Metal work, tons	914
Clearing, acres	200
Vitrified drain tile, lin. ft	21,500
Crushed stone (not in masonry), cu. yds	11,000
Timber and lumber, bd. ft	950,000

Stream control of the Esopus and Beaver Kill.

Each end of Olive Bridge dam terminates in a dike known here as the north and south wings. The other dikes are the east and middle west dikes, as shown in Fig. 2. The entire area of the surface which the dike will cover is first stripped of all surface soil and vegetable matter. A vertical trench is then excavated

Fig. 2. Map of Main Dams, Ashokan Reservoir.

to rock. A concrete core wall is then built in the trench, the average width of which is about 10 ft. at the bottom and 4 ft. on top. After the forms are removed the space between the concrete and the original earth is filled with clay and tamped to the

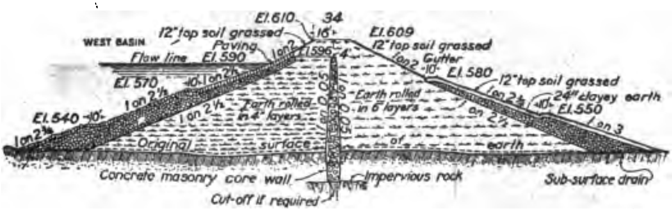


Fig. 3. Cross-Section of South Wing, Olive Bridge Dam.

original surface of the ground. At this point the embankment proper is started by spreading layers of earth 4 ins. thick on the water side and 6 ins. thick on the dry side of the dike. These layers are then rolled with 12-ton Monarch and Kelley steam rollers. The rollers are of special design, having an unusually

high horsepower for their weight. The embankments have slopes of 1 on 2 above water level and 1 on $2\frac{1}{2}$ below water. These slopes are, however, covered with "Class C" rubble riprap. Above water line the slope is surfaced with top soil and grassed.

Material was hauled to the embankments in cars and was

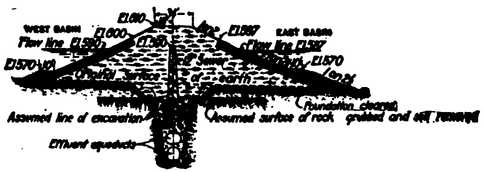


Fig. 4. Earth Section, Dividing Weir Dam.

spread in layers $1\frac{3}{4}$ times as thick as the required layer and was then rolled down. Spreading was done largely by hand and all stones too large for rolling into the layers was picked out and used for "Class C" riprap.

The Lahontan Dam. This dam for the Truckee–Carson Irrigation Project is founded on an unsatisfactory base. Water-bearing passages of small or moderate capacity are of frequent occurrence

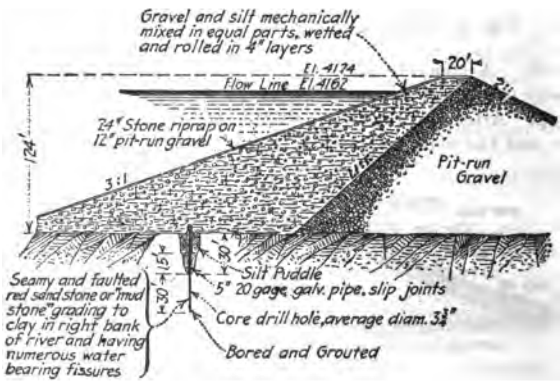


Fig. 5. Section Through Lahontan Dam.

in the bed rock. The treatment of this foundation with grouting from drill holes is described in *Engineering News*, Apr. 3, 1913.

Much study was given to the character of structure which could safely be built on this foundation to withstand a reservoir head of 120 ft. The original proposal of a gravity masonry dam

was abandoned, and finally the embankment type with deep cut-off wall was adopted, as illustrated in cross-section in Fig. 5.

Dams for the Porto Rico Irrigation Service. These are described in *Engineering and Contracting*, Jan. 19, 1910, and June 22, 1910. From these articles Figs. 6 to 8 are taken.

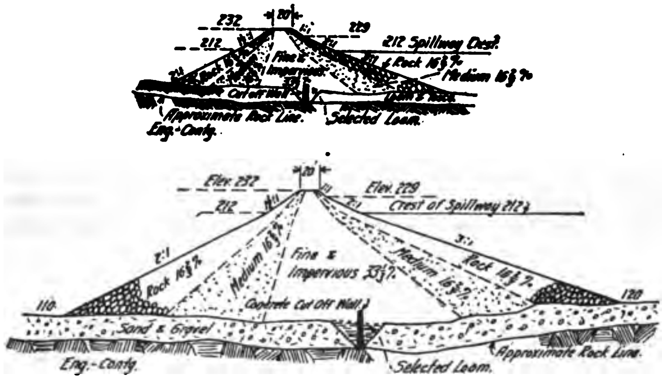


Fig. 6. Sections Near Center and End of Patillas Dam.

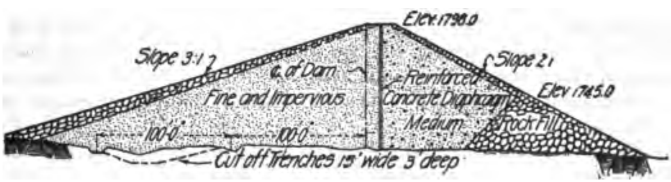


Fig. 7. Earth Dam at Guyama.

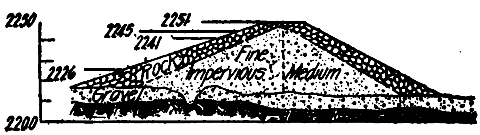


Fig. 8. Earth Dam at Villaba.

The Patillas Dam comprises some 950,000 cu. yds. excavation and fill for dam, spillway, tunnel, etc. The Caute, located near Guyama, requires 196,200 cu. yds.

Dams for Miami Valley Flood Protection. *Engineering News*, Jan. 25, 1917, describes in detail the design of earth dams and

their appurtenances which are to be used in protecting the Miami Valley in Ohio against floods. The engineers aimed at ample safety of the structures, and definite knowledge with respect to all conditions of service and operation. This is shown by the adopted dam section, Fig. 9.

Construction of an embankment either by roller compacting (in layers) or by hydraulic deposition was decided to meet all requirements, without lining or core wall. A cutoff trench to go down 30 ft. or so, well below the surface layers, will be used.

The section adopted is distinctly more ample than that of the latest and strongest existing dams on tight or semi-permeable foundations — though, of course, not comparable with the Wachusett or Gatun type. It is proportioned for specially wide base. The features are frequent berms, concaved sides and symmetrical outline; that is, upstream and downstream faces alike

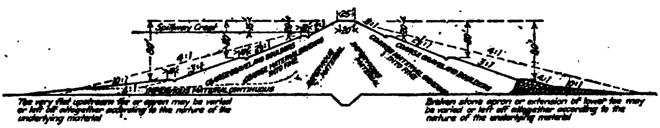


Fig. 9. Typical Cross Section of Miami Conservancy Dams

(because these are dry dams). Compared with the standard embankments of the Board of Water Supply of New York City, the upper berm is nearer the top and the slopes flatten out more toward the bottom, to a maximum of 4 to 1. Toe protection of broken stone sloped 10 to 1 may be added if found convenient or desirable.

The slopes are to be grassed, top soil being placed on the embankment for this purpose.

Slope drainage (for surface water) is accomplished by paved berm gutters and connecting gutters down the slopes. The chance of deterioration from settlement or any other cause is held to be vanishingly small with gutters, as compared with buried pipes.

The cutoff trench is indicated in Fig. 9, although local conditions will determine its depth. It is intended mainly to give most intimate connection between the impervious dam core and the subsoil, and thereby prevent seepage along the base. In all cases the dams will be built on ground stripped of top soil. The subsoil contains very little bedded porous material, so far as the borings and test pits revealed; in the process of making wash borings, the pipe lost its water only rarely. Geological indications are that any porous deposits are local; that is, have little horizontal extent. It is also important to recall that underwash-

ing of a dam is a slow process, while here the water will never stand behind the dam more than a short time.

A Dam Built Partly of Cinders. Harrison Souder, in Proc. Am. Soc. C. E., Vol. XL, describes the Hinckston Run dam, built in 1901 at Johnstown, Pa. Foundation difficulties, which were treated by injection of grout, are the subject of Mr. Souder's paper.

The original Hinckston Run project called for an earth dam, 60 ft. high, to retain some 400,000,000 gals. of water, with a depth of 45 ft. at the breast. The intention was to build a dam with a clay core, but, as an unlimited quantity of cinder from the steel plant was available, it was decided, after the work was started, to use this as backing for the dam, in place of earth, and eventually to fill the whole valley below with this material, thus rendering the structure practically unbreakable. In view of this and the additional expense incurred in making the cut-off tight,

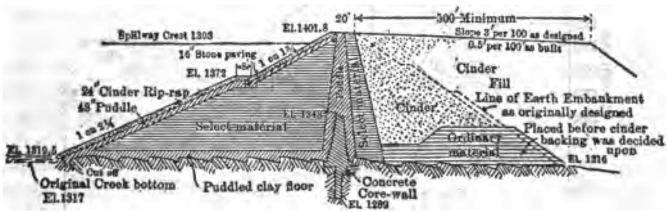


Fig. 10. Maximum Cross-Section, Hinckston Run Dam.

the proposed height of the dam was increased to 80 ft., and later to 85 ft., above the original creek level. This gave a total maximum height above the bottom of the core-wall ditch of 112.8 ft., a depth of water at the breast of 73½ ft., and a capacity of 1,100,000,000 gals. The lake thus formed is 1¼ miles long. The water-shed above the dam is 10.75 sq. miles.

The cross-section of the dam as built is shown by Fig. 10. The lower inner slope is 1 on 2¼, with 4 ft. of puddle and 24 ins. of cinder riprap. The slope above the berm is 1 on 1¾ with puddle lining diminishing to 2 ft. thick at the top. The facing is hand-laid stone paving. The puddle wall is 16 ft. thick at the top of the concrete core-wall, and diminishes to 4 ft. at the top of the dam.

Hydraulic-Fill Dam Built of Lava. J. W. Swaren, in *Engineering News*, Mar. 29, 1917, gives the following:

A coreless earth dam has been built by the Lewiston-Sweetwater Irrigating Co., in western Idaho, where the only available

soil was lava ash and weathered lava. In spite of the nature of the material, the maximum seepage is small.

The dam at present is 442 ft. wide on the base, 54 ft. high, and 1,550 ft. long. It is designed for an ultimate height of 85 ft. and a crest length of 3,600 ft. Its present storage capacity is 2,466 acre-feet; when completed, its capacity will be 6,682 acre-feet. The upstream face has a slope of 1 on 3, while a slope of 1 on 2 is given the downstream face. At the point selected for the dam the profile of the ground surface is rather uneven; upstream a fill of 9 ft. was necessary to bring the prism to the grade of the axis. A puddle trench, 8 ft. deep and 10 ft. wide, is placed along the axis.

Construction began in 1906. The surface of the ground was stripped and scarified. During the spring months a dike along

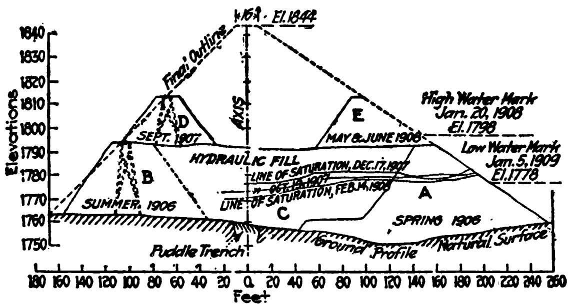


Fig. 11. Section Through Lewiston-Sweetwater Lava Dam.

the upstream toe (*A*, Fig. 11) was raised about 34 ft. The earth was placed in 6-in. layers by wheeled scrapers, sprinkled, rolled and harrowed. During the summer months a similar dike (*B*) was built along the downstream toe. The material for this dike was dumped dry from a trestle. So far as possible, all material composing the dam prism has been taken from borrow pits inside the flooded area, in order to increase storage capacity. Puddle clay for sealing the toe was obtained from a small deposit near the north end.

While the dike along the downstream toe was being built, water for the irrigation season of 1906 was stored behind the upstream dike. During the fall and winter of 1906 and the spring of 1907 the prism (*C*) between these dikes was filled by a unique combination of water settling and dump-cars. Water from the main canal was conducted into the area between the upstream and the downstream dikes. Earth was dumped into this water from cars

running on rails laid along the top of the upstream dike, the water in the pond between the dikes settling the earth firmly and at minimum cost.

Water was stored and used for the irrigation season of 1907; and no additional work was done on the dam until September, when a second dike (*D*) was made on the downstream toe, with its base on top of the fill already in place. The material was dumped from cars on a trestle and settled by water from a 1½-in. hose.

Additional land coming under irrigation, a larger storage was required. Financial conditions were unsettled at this time, and completion of the dam was out of the question. As the cheapest method of securing the desired capacity, a dike (*E*) was built on the upstream toe, with its base on the fill already in place. This was built by dumping from cars on a track laid along the center of the fill; the earth was moved both ways by scrapers. This work was stopped at El. 1814, providing for a total storage of 2,466 acre-feet, with water level at El. 1810.

The inner face of the dam displays the effect of wave action, each day's draw-down showing clearly in a little bench washed out of the fill. As the line of saturation is rather flat and shifts rapidly, the maximum storage is not made until the last snow run-off. The first irrigation period, closely following, draws down the water level well below the saturation line. During high water in the reservoir, careful watch is kept on a line of test pits along the downstream toe of the dike.

Drainage at the downstream toe is carefully developed, and no waterlogging of the prism occurs. At high-water period this drainage is 0.033 sec.-ft. After the close of the irrigating season, with the water at the level of the outlet pipe, drainage is only 1 cu. ft. in 29 min., indicating that in spite of unfavorable materials an excellent bond has been made between the dam and the original ground.

A Reservoir Embankment with Concrete Slope. This work is described by J. C. Ulrich, Proc. Am. Soc. C. E., Vol. XXXIX, and abstracted in *Engineering and Contracting*, June 11, 1912. The embankment, which is about 3½ miles long, forms about one-third the perimeter of the Prewitt Reservoir in the South Platt River Valley in Colorado. It has a maximum height of 36 ft. for about 100 ft., with a height not exceeding 25 ft. for the greater portion of its length and an average height of 20 ft. See Fig. 12.

The material on which the embankment is founded, and of which it is constructed, consists of very fine sand mixed with a small percentage of soil.

Before depositing any earth for the embankment proper, the

intercepting trench was partly filled with water, in which selected material was deposited in 2-ft. layers. This operation was repeated three times in the filling of the trench. The water for this purpose was pumped from a series of 16 wells, put down just outside of the lower toe of the embankment, at intervals of about 1,000 ft. Sufficient water was thus furnished and used to effect, not merely the moistening, but the actual puddling, of the material deposited in the trench.

The purpose of this puddled trench was to break the continuity of any seam which there might be between the soil of the site and the material of the superimposed embankment. It was also designed to cut off and intercept the channels of any dog or gopher holes which might be in the material underlying the embankment.

After the trench had been filled, and the site had been cleared of all vegetable matter and plowed to a depth of 10 ins., the construction of the embankment proper was begun.

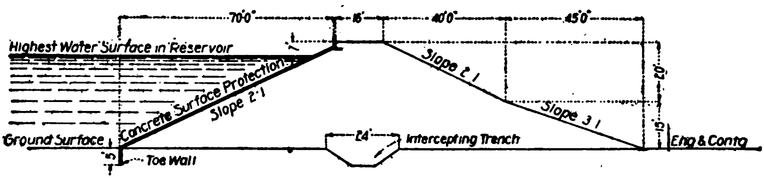


Fig. 12. Typical Section of Prewitt Reservoir Embankment.

The earth was deposited in layers not exceeding 1 ft. in thickness. Each layer was then thoroughly wetted, before the deposition of the next, with water pumped from the wells. Then it was rolled with a corrugated roller weighing 125 lbs. per in. of length. This operation was repeated successively until the full height of the embankment was reached. The wetting of this material prior to each rolling resulted in the actual wetting of the whole layer, not the mere moistening of the surface. The contractors kept records of their pumping operations, and these disclose the fact that the volume of water pumped into the material exceeded that of the embankment itself; in other words, the volume of water put into the embankment exceeded that of the earth.

The water side of the embankment is protected against wave action by a covering of concrete, 4 ins. thick, extending from its foot to within 2 ft. of its top, where it joints an L-shaped vertical parapet wall of reinforced concrete.

At the foot of the surface protection, and connected therewith by reinforcing rods of steel, there is a reinforced vertical "toe-

wall," extending 5 ft. into the ground below the edge of the latter.

The concrete slope is laid in slabs 10 ft. wide. Beneath the slabs and along the joints are reinforced concrete stringers, 6x12 ins.

Small Earth Dams for Stock Watering Reservoirs. Many of these dams have been built by the Chicago and Northwestern Ry. between its terminals and the ranges in Dakota and Wyoming. According to *Engineering and Contracting*, Sept. 20, 1911, these dams were built of natural prairie soil with teams and scrapers at an average contract price of 15 cts. per cu. yd. Generally they are not over 15 or 16 ft. high, the maximum being 24 ft. The cost per acre-ft. of water impounded ranged from $6.82 for a reservoir holding 186.1 acre-ft. to $72.40 for one holding 9.3 acre-ft.

A feature of these dams is a wave fence, built the full length

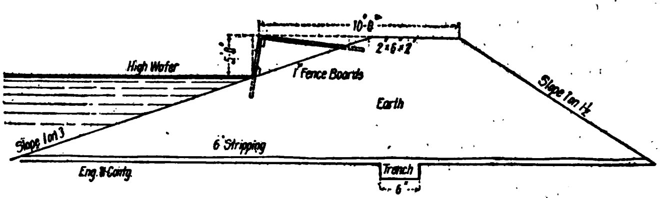


Fig. 13. Cross Section of Earth Dam Showing Wave Fence.

of the slope that is reached by water when the reservoir is full, it is intended to prevent wave erosion. See Fig. 13. A typical dam contains 100 acre-ft., has a top length of 260 ft., a maximum height of 14 ft., and costs $2,300.

Determining the Percolation Factor. A. M. McPherson recommends the following method of procedure in a paper in *Engineering and Contracting*, July 5, 1911: A uniform sample of the material to be used in the construction of the dam should be taken. It should be thoroughly mixed so as to resemble as nearly as possible the material as it would be placed in the dam. This material should then be placed in a tank which has been constructed for the purpose. A tank 4 ft. wide, 4 ft. deep, and 22 ft. long is large enough to give satisfactory results. A miniature dam is then constructed upon the profile which has been tentatively decided upon, say 3-1 on the inside or water face, and 2-1 on the dry face. The earth should be tamped in, moistened slightly, and made as compact as possible. Pieces of gas pipe with holes bored along their sides and covered with pieces of wire netting, should be sunk at intervals of about

a foot, beginning at the axis of the dam and extending on through the dry face. Water is then admitted on the 3-1 side to a level proportionate to the heighth of the dam, and is kept at this mark until water remains at a constant level in the pipes sunk in the lower side of the dam. This will probably cover a period of several weeks. The depth of the water in the pipes is generally determined by means of a measuring rod. Taking the difference in depth of the water in the various pipes and knowing their distance apart, the angle of saturation is easily calculated.

The angle of repose is obtained by trying successive slopes to determine how steep a slope the material will stand when subject to water. This test should be supplemented by another. Have the tank full and suddenly let the water out and note the behavior of the material. Often this will show what was supposedly a safe slope is too steep, as slips will occur as the water is being let out of the tank. It is well after these tests have been made to let the material dry out and notice whether it cracks or shrinks badly. If the material in the miniature dam does not answer satisfactorily to all the tests imposed, it should be discarded and some other material tester, or a mixture of the material in question and some other should be tried.

Shrinkage of Earth in a Dam. R. M. Hosea in *Engineering and Contracting*, Apr. 1, 1908, gives the following data on the construction of a dam for the Sugar Loaf Reservoir in Colorado: The entire area of the dam site was overgrown with willows and some trees, and in the lowest portion was covered with 1 to 2 ft. of black muck. All of this was moved, giving a firm clay foundation for the earth work. The surface was benched and furrowed. Borrow pits were laid out on the inside of the reservoir site over a large area and stripped of all vegetable matter, exposing the clay sand mixture, containing some boulders, beneath which was a clay sheet four or more ft. thick. The cross section of the reservoir dike was about 200 ft. on the base, 25 ft. on the top, with a height of about 40 ft. The inner slope was 3 to 1, while the down stream was 2 to 1.

The base was made of moist clay and well puddled. Around all pipes and masonry this clay was placed by hand and tamped. The up stream face was made for a thickness of 20 ft. of the best clay obtainable, the center of the dike prism being of selected material, while the poorest material was all placed in the down stream face. The dam was carried up in thin layers. The whole was smoothed, sprinkled and rolled with a heavy steam roller. The formation of layers was carefully avoided by depositing loads irregularly.

Elevating graders were tried for a time, but the presence of boulders made their use inadvisable, consequently a small steam shovel was used to load into wagons, the material being deposited in that manner.

There were 95,388 cu. yds. of earth excavated for the dam prism, while the actual cross section of the dam showed 90,200 cu. yds. The dam remained partly completed through one winter, which gave the embankment a chance to become compacted. Throughout the entire work it was sprinkled and rolled. These figures show a shrinkage during construction of 5.44%. Mr. Hosea does not state that any tests have been made to show settlement of the dike since the reservoir has been in use.

See Chapter I for data on earth shrinkage.

The Tabeaud Dam and Its Cost. The Tabeaud Dam is described by Burr Bassell in *Engineering News*, July 10, 1902. Mr. Bassell is also author of a book on this dam.

The Tabeaud Dam was built in 1900 and 1901 by the Standard Electric Co. of California as part of a hydro-electric development.

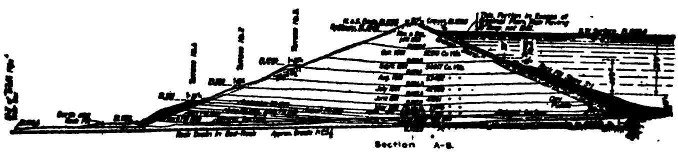


Fig. 14. Section of Tabeaud Dam.

It is located about 3 miles from Jackson in Amador County California. The crest of this dam is 123 ft. above the natural surface of the ground at the foot of the lower slope, and 120 ft. above rock vertically beneath the crest. See Fig. 14.

The dam has a crest length of 636 ft. and varies from 50 to 100 ft. in length at the base. It is 20 ft. wide at the top and 620 ft. wide at the bottom. The total volume of the structure is 370,350 cu. yds., and its weight is about 665,000 tons. The dam was designed to have a puddle heart-wall for its whole length, 8 ft. thick at the top and increasing in thickness towards the bottom. A portion of this was built, but it was discontinued after it had reached a height of 24 ft.

Foundation Drainage. Most of the dam rests on firm hardpan and the balance on rock. The excavation extended to rock beneath both the axis of the dam and near the foot of the inner slope where the puddle face wall abutted against the hillsides. Nearly all the bedrock is of slate, with a dip of some 40° upstream and a strike of 15° with the center line of the dam. About 150 ft. above the center line a quartz vein crosses the valley, on

the line F B T. Between this line and the longitudinal axis the rock was satisfactory, but above the quartz vein fissures and springs were found.

To remove this spring water and to intercept seepage beneath the whole length of the dam, a system of bed rock drainage was constructed. Water from the springs is led to a central point in trenches in the bed rock. The bottoms of these trenches were leved with concrete over which was placed an inverted V-flume, Fig. 15. From the central collecting point water is lead through a 2-in. pipe which is covered with an inverted V-flume (angle

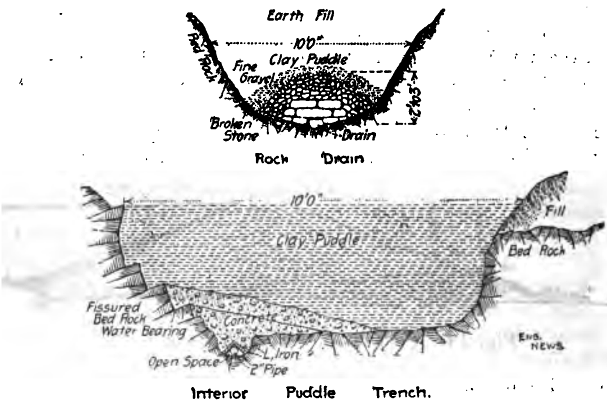


Fig. 15. Details of Foundation Drainage.

iron). This pipe carries it down stream to the beginning of the bed-rock drain. The inverted flumes of angle iron were covered with concrete which in turn was covered with clay puddle.

The hill side drains were located approximately parallel with and 8 ft. below the longitudinal axis of the dam, and were carried to Elev. 1,250. The trench ranged in width from 5 to 10 ft. and extended varying distances into the rock, according to the character of the latter. The stringers and capstones of these drains were carefully selected and laid. All crevices were then filled with spalls and a covering of 1 to 3-in. broken stone from the tunnel dump was put on to a depth of 18 ins. Above the stone the trenches were refilled with choice thoroughly puddled clay.

Observations at a small weir at the outlet of the drain indicate a quite constant seepage of about 13 gals. per min. The maximum discharge has been 180 gals. per min. during a heavy rainstorm.

Building the Embankment. The material for the dam was all obtained close at hand. The earth was taken from borrow pits within the reservoir basin at the sides of the reservoir and at the ends of the dam. Most of the rock-fill facing came from the tunnel dump and the balance from quarries in a ravine to the south of the dam. It was hauled in carts and stick-wagons. The company built only 40,000 of the 370,350 cu. yds. of the bulk of the dam. It had a small steam shovel and some cars on the ground, but the extent to which it used these is not stated.

The contractor used a larger steam shovel, of 1½ cu. yds. capacity, for about a month, but it mixed so much stone with the dirt that the engineer was not satisfied with it. The contractor used fresno scrapers to bring the earth from the borrow pits to a loading platform, or trap, consisting of a timber platform with a hole about 20 by 40 ins., through which the wagons were filled. With good material, 8 of these scrapers could fill 25 bottom dump wagons per hr., each wagon having a capacity of 3 cu. yds. The average haul for the entire earth work was one-fourth mile.

The maximum equipment of the contractor was as follows: One 1½ yd. steam shovel; 37 dump wagons; 11 rock wagons and carts; 39 fresno scrapers; 21 wheel scrapers; 8 road and hill side plows; 3 road graders; 3 sprinkling wagons; 2 harrows; 2 rollers (5 and 8 ton); 233 men; 416 horses and mules. The wheel scrapers were not used.

The stripped surfaces were wet by means of hose and nozzles before the embankment was started. The earth was dumped in rows, generally parallel with the longitudinal axis of the dam and ranged from the axis toward the slopes. At the ends of the dam a few rows were frequently made parallel to the intersection of the embankment and the hill side. The best material was placed at the ends and on the up stream half of the dam. The top surface was kept basin-shaped, giving a slope of about 1 on 25 from the sides to the center. The puddle heart-wall was discontinued at elev. 1,160 and more attention given thereafter to puddle on the inner face. This change from the original plan was made by Mr. Bassell soon after the contractor started work, because of the character of material available, and the excellent results obtained in securing an homogeneous earthen mass, practically impervious. Besides, the central puddle wall would have greatly interfered with the progress of the work and delayed the completion of the dam.

The central section of the embankment, however, received more water than other portions which were not strictly puddle, on account of the basin shape and manner of wetting. Any excess of

water in this portion would be readily taken care of by the cross-drains.

The contract specifications provided that the puddling material should contain about 70% of clay and about 30% of gravel less than 2 ins. in diameter.

Rock-pickers and carts followed the dumping wagons, removing all roots and stones which would not pass through a 4-in. ring. The specifications provided that no stone weighing over 5 lbs. should be allowed in the dam, and that "layers of rocky material must alternate with layers comparatively free from rock." All the waste was dumped outside the slope line, after which the roots were burned.

Six-horse road-graders leveled down the rows of dirt and were followed, in turn, by harrows and rollers, with sprinklers interspersed, as was found necessary. By properly spacing the dirt loads and rows, layers of any desired thickness could be secured, while the graders made as smooth and uniformly thick a layer as could be asked. If the material was dry, it was sprinkled as soon as the graders had given it a general leveling; otherwise there was no sprinkling until between the harrowing and rolling, and some of the time none was necessary then. The previous layer, however, was always sprinkled before a new one was added, and hose with nozzles were almost constantly employed for wetting down the outer slopes, the stripped hillsides and all points which the wagons could not reach.

One of the two rollers weighed 5 tons and had a 60-in. face, giving 166 lbs. per lin. in.; the other one weighed 8 tons and had a 40-in. face, thus giving 200 lbs. per in. The rollers were not grooved, but the loaded wagons passing over the layers cut the surface to a greater or less extent. The loaded wagons weighed over 6 tons apiece, or 750 lbs. per lin. in. of wheel tread. They were made to travel where they would do the most good, particularly near the edge of the inner slope and along the ends of the embankment where it joined the hillside. Generally the rollers were drawn lengthwise of the dam, but they frequently went crosswise at the ends and also round and round a portion of the surface. The contract specifications stipulated that each 100 cu. yds. of material should be rolled 1 hr., or compressed to an equivalent amount and that the compression should be sufficient to prevent quaking when a loaded wagon passed over the area.

The specifications provided that for the first 60 ft. the layers should not exceed 6 ins., and above that level 8 ins. in thickness. The average thickness of the finished layers under the contract work was as follows: April, 4 in.; May, 3½; June, 4; July, 4½;

August, 5; September, 6; October, 7; November and December, 8 ins.

Tests of the material used in building the dam, made in June and Sept., 1901, showed the following average weights of 1 cu. ft. of material under different conditions: Dust dry soil, 84 lbs.; fully saturated, 101.7; natural bank, 116.5; delivered from wagons, moist and loose, 76.6; loose dirt from dam, shaken down and measure struck, 80; test pits in dam, 133 lbs. The earth from the test pits in the dam contained 38% of gravel and grit. The natural soil had 19% of moisture; 33% of water had to be added to it for saturation. The voids were 52% of the total. The angle of repose of the moist earth from the bank was 44°; of dust dry dirt, 36%; of saturated dirt, 23%. The cuts at the borrow had vertical sides.

Cost of a Dam in Utah. An earth dam for the mammoth Reservois in San Pete County, Utah, is described by J. C. Weelon in *Engineering News*, Oct. 15, 1914:

The dam is designed to be 125 ft. in height, eventually, and is built of earth on both sides of a concrete core wall. The core has buttresses on both sides opposite each other, starting 20 ft. wide at bed rock and tapering on a batter to zero at the top of the dam, and spaced 20 ft. apart along the wall. The dam is being built only so fast as the irrigation demands of the farming district require; it has been six years under construction; and, is now at the 67-ft. level. The present area of the dam covers one-sixth of an acre.

The first work on the earth fill was carried to the 15-ft. level by dump wagons, the earth being rolled with a corrugated roller of 8 tons weight, drawn by four horses. The next 25 ft. was carried on by water. A ditch carried water along the brow of the hillside 150 ft. higher than the work. Teams and plows would make furrows straight down the hill slope from the ditch to the work level on the dam. A small quantity of water released from the ditch into the furrow washed the entire furrow upon the dam, while the teams were coming back up the hill to engage another furrow. The free water was carried off the work in an improvised culvert through a dike at the extreme up- and down-stream faces of the dam, which was carried a few feet higher than the puddled and thus impounded it. This method was found objectionable because the heavy and coarser material, weighing 2,100 lbs. per cu. yd., dry, would repose next to the hillside, while the very fine clay, weighing 1,500 lbs. per cu. yd., dry, would carry in suspension to the center of the work. It was found so difficult to extract the water from this fine clay that the sluicing process was abandoned and rock and gravel were thrown

into this puddled and bottomless mass from the edges until men and teams could travel over it. The work is being finished by the use of scrapers and wagons. The cañon slopes are covered with a soil of clay and fine gravel which is of fine quality for use in the construction of an earth dam.

The dam is being built without any modern machinery, except the smallest stream concrete mixer made. A 12-mile dug-way through a precipitous cañon renders the hauling of heavy freight very difficult. The roller was cast in seven sections so that, with the frame, eight loads could be made of it.

The earth fill is costing 38 cts. per cu. yd., and the concrete $9.37 per cu. yd. The overhead charges are nominal.

Use of Goats for Compacting Puddle. Work on an earth dam at Santa Fe, N. M., on which goats were used for compacting the puddle, is described in *Engineering News*, Apr. 13, 1893. This dam, 85 ft. high and over 1,000 ft. long, was built across the Rito de Santa Fe. The upper half of the dam site was excavated to rock, and the rock washed with water by means of hose.

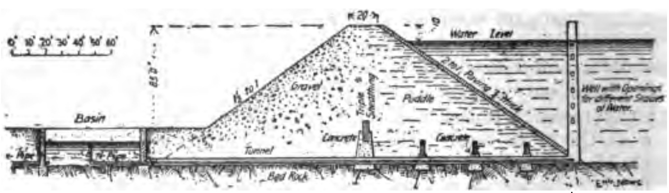


Fig. 16. Cross Section of Dam at Sante Fe, N. M.

The general character of the structure is shown by Fig. 16. The triple sheeting inserted in and carried above the concrete trench and heart walls consists of three thicknesses of 1-in. boards, nailed together horizontally.

The upper half of the dam is puddled in layers, a herd of 115 goats having been bought expressly for puddling. These goats are in charge of a herder, who keeps them in motion when on the dam, which is stated to be from 12 m. to 1 p. m., and from 5 to 6 p. m. each day.

In commenting on this use of goats in a subsequent issue of *Engineering News*, J. M. Howells, who was on the work, says: "It was subsequently found that as the travel of the goats did not interfere with the teams, it would be more convenient and economical to use a less number of goats and keep them at work all day. As a result of our experience, we find that 115 goats

by constant use would do well the puddling for 30 wheel scrapers, averaging about 14 cu. ft. per load on about 500 ft. haul.

"The material was first spread while dumping, next leveled in a 3-in. layer by dragging a beam, next sprinkled with a sprinkling wagon, and then puddled by the goats. The puddling was thoroughly done in this way, and the surface left just rough enough for good joint with the next layer.

"As goats in this arid region are a dry hillside animal, I feared such a radical change in their habits as keeping their feet muddy all day would bring on foot disease. No lameness had appeared among them up to six weeks ago, and I have had no word of any since; it seems likely their hardiness will carry them through.

"When the goats were first put to work they tired easily, and were able to stand it but a part of the day; we learned this was upon account of the scanty range upon which they had fed, having to rely mostly upon browsing the juniper brush. A few days, however, of feed on peas and refuse hay brought back their accustomed good spirits. And, after their day's work was over, they would butt each other around the corral with the enjoyment characteristic of this singularly precocious animal."

A Mechanical Flock of Goats. In the preceding paragraph the efficiency of the goat as an earth compacting device is praised. Several years ago a contractor engaged in road building in California learned that a sheep's feet can compact loose earth so hard that a pick-pointed plow will loosen it with great difficulty. He had just plowed up a road when several thousand sheep walked over the loosened soil. The compacting action of their hoofs was so effective that he said: "If those sheep had only postponed their visit a few hours until I had graded the earth, I would have gladly paid their owner for their work." Then it suddenly occurred to him that although he could not hire sheep, he might invent a flock of them, which he did. He made a roller with projecting lugs, like sheep's feet, and used it for consolidating subgrades of roads and streets. It is probably the most efficient device available for compacting earth in embankments.

This rolling tamper, or tamping roller, is made by W. A. Gillette, South Pasadena, Calif. It is illustrated in Chapter VI, and its use for reservoir embankments is described later in this chapter.

Earth Dam Compacted by Irrigation Flooding. *Engineering and Contracting*, July 18, 1917, describes the construction of an earth dam for Reeves County Irrigation District No. 1 in Texas. The dam contains 180,000 cu. yds. of material which was exca-

vated from the bottom of the reservoir by western elevating graders and hauled to place in western dump wagons.

In the construction of the dam the somewhat unusual method of compacting the earthwork by irrigating was employed. The distance of the work from the nearest source of water supply made it impracticable to follow the common method of sprinkling by wagons, and large quantities of water being necessary in the work of puddling, as well as for stock and other purposes, it was thought best to provide a constant supply. This was provided by means of a small ditch nearly 3 miles long, diverted high enough to carry water over the top of the completed dam.

Fig. 17. Method of Retaining Water in Puddling.

In order to cut off a gravel stratum at the dam site a trench averaging 40 ft. wide at the top and from 5 ft. to 15 ft. wide at the bottom, and 10 to 20 ft. deep was excavated to rock or clay foundation. This was filled with water and good earth material "bulldozed" in from the end. Over this puddled trench the dam, which is 47 ft. high and 2,500 ft. long was built in 3-ft. lifts. Each lift or layer as completed was bordered and cross-bordered where necessary, and flooded with water as shown in Fig. 17. This water was allowed to stand for several days, the intention being to permit the moisture to connect with that of the lift next below. On testing out these lifts with a post hole digger after irrigation, it was found that the earth was well compacted, and a very complete impervious settlement obtained quickly. This pocess of settling and compacting the material was continued to the very top of the dam.

Elevating Graders on the Stanley Lake Dam. M. E. Witham, in *Engineering Record*, Dec. 11, 1909, gives cost data on the use of elevating graders and dump wagons on part of the Stanley Lake Dam. This dam is an earth embankment designed to have an ultimate heighth of 141 ft. and a maximum length of 9,140 ft. at the crest. When the construction was first started a dike was placed along the toe of both slopes of the ultimate section. These dikes were 30 ft. high at the lowest point in the valley across which the dam is being built, and were made to a top width of 30 ft. during the working season of 1908. The material for the dikes was excavated by elevating grader machines from borrow pits directly above and below the site of the dam, and was delivered from these machines to place by 1½-yd. dump wagons.

The material handled was largely surface soil and clay, underlain by a thin stratum of sand and gravel that was used to some extent in the dikes. None of the materials had to be blasted, but it was necessary to loosen them with a plow in some cases. The ground between the borrow pits and dikes was level enough to eliminate difficulty in hauling over it. The dikes also were kept in such shape that no snatch teams were necessary to assist in moving the wagons on them. The grading was under way in July, August, September, October and November, 1908, during which time the amount of rainfall was so small that it did not interfere materially with the operations. (A slide occurring on this dam in 1916 is described at the end of this chapter.)

In computing the cost of labor the wages paid were increased 50 cts. per day per man for board, including Sundays. Feed for the horses and mules used on the machines and wagons was calculated at 82 cts. per head per day, also including Sundays. A mixture of corn, oats and bran, costing $1.80 per 100 lb. was used, 10 (100-lb.) sacks being required each day to feed 128 horses, or 48 cts. per head. Alfalfa at $11 per ton was used for rough feed, one ton being the average amount necessary to feed 128 head one day, or 27 cts. per head.

The standing force which had to be distributed over the entire contract was as follows:

1 Walking Boss at $125 per month, plus board	$5.31
1 Foreman at $100, plus board	4.34
1 Foreman at $75, plus board	3.38
1 Timekeeper at $75, plus board	3.38
1 Blacksmith at $60, plus board	2.81
1 Blacksmith's Helper at $1.75 per day	1.75
2 Coral Men at $45 per man	4.46
1 Water Boy at $1.75 per day	1.75
Total per day	$27.18

The cost of the 2-horse dump wagons per day was figured as follows: Driver at $1.75; feed for two horses, $1.64 and 25 cents for depreciation, making a total of $3.64. When three horses were used to a wagon this was increased by the cost of feed for one horse to $4.46 per day. The working day was 10 hrs. Three of the elevating grader machines were used while most of the work was in progress, one of them being pulled by a traction engine and the other two by horses. On one of the horse-drawn machines 12 head of stock were used and 14 head on the other. The figures given are for the 12-horse machine, while the added cost of the 14-horse machine was taken as the expense feeding two more horses, or $1.64 per day.

COST OF OPERATING ELEVATING GRADER MACHINES

Machine Hauled by Twelve Horses —	
Elevator man at $45 per month, plus board	$2.43
Pilot man at $35 per month, plus board	1.85
Plowman at $45 per month and board	2.23
Push man at $30 per month and board	1.65
Dumper at $2 per day	2.00
Feed for 12 head of stock	9.84
Depreciation	1.50
Cost per day of Twelve-Horse Machine	$21.34
Machine Hauled by Traction Engine —	
Engineer at $100 per month and board	$4.27
Fireman at $60 per month and board	2.74
Pilot at $35 per month and board	1.78
Plowman at $45 per month and board	2.16
Dumper at $2 per day	2.00
Fuel, 1½ tons at $3	4.50
Hauling water, with two horses	3.44
Hauling coal, half day	1.72
Lubricating oil and depreciation	3.50
Cost per day of Traction Engine Machine	$26.11

During the month of August the cost with the traction machine was 13.3 cts. per cu. yd.; the cost with the 14-horse machine was 13.5 cts.; and with the 12-horse machine 12.6 cts. Similar data recorded during the month of September gave the cost for the traction-engine machine as 14.1 cts; for the 14-horse machine, 12.4 cts., and for the 12-horse machine, 12.5 cts. During that month practically no time was lost, and the conditions obtained were generally the same as in August. In October the weather was such from the the seventeeth to the twenty-fourth, inclusive, that the machines were not in use. During this month the 14-horse machine was operated at a cost of 12.33 cts. per cu. yd. On the other horse-drawn machine 12 head of stock were used for the first week, then that machine was drawn by the traction for three days, after which the engine was laid up and 14 head of stock used for the time during the balance of the month when condi-

tions permitted work to be done. The cost with this machine for October under these conditions was 13.03 cts. per cu. yd.

During all of November only two grader machines were operated, each of them being hauled by 14 head of stock. Both machines were used 14 days, work being interrupted for six days at the middle of the month and operations ceasing on Nov. 27. The average haul was somewhat less during this month, but other conditions were about the same as those above given. The cost with one machine was 12.7 cts. per cu. yd., and with the other machine 13.07 cts. per cu. yd.

Early in November 850 cu. yds. of material were placed in a small dike by means of Fresno and slip scrapers. The haul in this case averaged about 100 ft. and the materials were much the same as those moved by means of the grading machines and wagons. This work cost only 6 cts. per cu. yd.

In comparing the cost of the operation of the different grading machines it should be noted that the traction engine did not work to advantage. The disadvantage of the engine was due principally to two reasons: First, the alkali nature of the surface waters used in the boiler occasioned delays, and trouble on account of foaming and scale. In the second place, moist and slippery ground handicaps the operation of a traction-drawn grader more than those of one drawn by stock. Over the period of this cost analysis several wet days consequently rendered conditions rather hard on the engine drawn machine.

The actual average working time per hour for the elevating grader machines was about 45 mins. For a haul of 500 ft. seven wagons to a machine were found to give the greatest effiiciency. For each 100 ft. of haul it was considered that one wagon should be added. As a general rule one wagon was considered to haul 1¼ cu. yds. as measured in the embankment.

It is evident that, interest, administration, camp equipment and similar overhead expenses are not included in the costs.

Embankment for an Oil-Storage Reservoir. E. D. Cole, in *Engineering and Contracting*, Nov. 24, 1915, gives the following:

The general dimensions of the reservoir are as follows: Inside diameter, bottom 462 ft., top 528 ft.; depth 22 ft.; width of top of embankment, 11 ft.; inside slope 1½ to 1; outside slope 1½ to 1; thickness of concrete lining, bottom 3 ins., top 2½ ins.

Earthwork. The formation at the site was a light sandy clay, and this was easily handled by the Fresno and wheel scrapers used throughout the work. After the site was cleared of all brush and grass, the foundation under the embankment was thoroughly plowed and wet down before the fill was started. Water for moistening the material was supplied through a 2-in. pipe

line laid around the site, just outside the outer line of slope stakes, with hose connections approximately 100 ft. apart. A 2-in. line was also run to the center of the reservoir to supply water to the portion of the site which could not be reached from the outside line. To avoid being in the way of the scraper teams, this pipe line was laid through one of the three 12-in. outlet pipes that were placed in position under the fill at the beginning of the work. A narrow trench was dug from the inner end of this outlet pipe to the center of the reservoir, and the 2-in. line was laid in it. This line was lowered from time to time as the work progressed, and was kept far enough below the surface of the excavation to be clear of the plow and scraper teams. Wetting down the excavation material was a help in several ways, as it not only made a more compact bank, but kept the dust down and made the earth ride better in the scrapers. This may seem inconsistent, inasmuch as the work was done during the rainy season, but can be readily understood on taking into consideration the fact that only 6 working days were lost during the winter on account of wet weather. The embankment was built up in thin layers, about 3 ins. thick, laid parallel to the floor of the reservoir, and well compacted. In addition to the tramping of the scraper teams, the fill was compacted by two petrolitic rolling tampers (see Chapter VI for illustration) which were driven continually around the top of the embankment.

To insure a compact and uniform backing for the concrete lining, on the inner slope below the natural ground surface, the excavation was started 2 ft. (measured normal to the slope) inside the inner line of slope stakes. This necessarily increased the quantity of excavation, and left the embankment short on the inner slope by this quantity. After the completion of the main portion of the embankment, a lining of selected material, 3 ft. thick (measured normal to the slope), was built up against the inner slope, from subgrade (1 ft. below floor grade) to the top of the finished fill. This extra foot of material was put on to insure a compact surface at the grade line of the inner slope, but was afterward removed, as will be described later: The refill is an important part of the construction because it would cut off any layers of sand or loose material that might be encountered in that portion of the inner slope which lies below the ground surface. On some previous work it was found necessary to excavate and refill portions of the natural embankment, below the ground surface, after the fill had been completed and trimmed to grade; this work caused considerable delay and added expense. One concrete-lined reservoir in this field partly failed, due to neglect of this part of the work, necessitating heavy expense in

emptying the reservoir, besides the loss of a considerable quantity of oil and the cost of patching the lining.

On the first reservoir, in which a refill was put in, the lining of selected material was started with Fresno scrapers, but these were soon abandoned in favor of wheel scrapers, on account of the difficulty in keeping them from sliding over the edge, and also because the wheel scrapers would build up a bench of the required width, and it was impossible to keep within the limits with the Fresnos. Apparently, the wheel scrapers build up a more compact lining.

Trimming Slopes. On the completion of the main embankment and the refill, the excess material on the inner slope, which ranged in thickness from 1 ft. at the top to 2 ft. at the bottom, was trimmed off leaving the slope smooth and true to grade. For this work of trimming the slope, a novel and (the writer believes) original method was used. Grade stakes were set on radial lines, both at the top and inner toe of the slope, approximately every 10 ft. around the circumference of the reservoir. Men with mattocks and slope-level boards then dug narrow trenches, 1 ft. wide and true to grade, from the top grade stake to the stake at the toe of the slope. Then 2 by 4-in. timbers, 38 ft. long, each faced with a narrow strip of strap iron, were placed in the bottom of each trench to act as guides for a trimming machine which was used to finish that portion of the slope between the hand-dug trenches. Before using the planer, however, all excess material above the top of the 2 by 4-in. timbers was scraped off the slope with a specially made Mormon or Buck scraper which was dragged up and down the slope; power being furnished by a double-drum hoisting engine at the center of the reservoir. The back-up line from the engine passed through a 12-in. snatch-block supported at the top of the slope on a portable wooden truss designed for that purpose. This wooden truss was anchored against over-turning by two heavy chains fastened to iron stakes driven into the top of the embankment. As each succeeding section of the slope was finished, the wooden truss was moved along the top of the bank with a team of horses.

After the bulk of the material above the top of the 2x4-in. timbers had been removed, a slope-trimming machine, designed and built by Mr. C. O. Zeller and the writer, was substituted for the Mormon scraper and used to plane off the remaining thin layer of earth and bring the slope to grade or flush with the bottom of the guides. Fig. 18 shows the trimming machine, which consists of a rectangular frame 11 ft. long and 6 ft. wide, built up of 6-in. steel channels bolted together and carrying two cutting blades. The cutting blades are of ⅜x12-in. flat rolled

steel, and are set at an angle with the frame of 1 to 2½. The blades are also set at a slight angle longitudinally with each other, and the cutting edge projects down 2 ins. below the bottom of the frame. The planer is dragged back and forth on the slope until the ends of the frame ride on the top of the guides, and that particular section is shaved off flush with the bottom of the guides, or down to grade. In this way nearly nine-tenths of the slope were finished by machine and at one-half the cost of doing the work by hand.

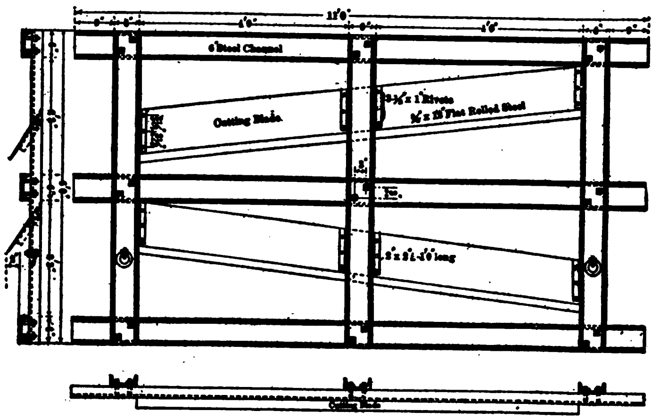


Fig. 18. Slope-Trimming Machine.

Concrete-lined reservoirs of this type cost, complete, from 9½ to 10 cts. per bbl. of capacity, depending on the location and other governing conditions. This cost may be distributed approximately as follows:

Cost of earthwork	$0.03 per bbl. of capacity
Cost of roof	0.03 per bbl. of capacity
Cost of concrete lining	0.04 per bbl. of capacity

Rolling Puddle on Reservoir Embankment Slope. *Engineering and Contracting*, Apr. 10, 1907, gives the following: Fig. 19 shows the method adopted for compacting an 18-in. layer of puddle on the slope of a reservoir embankment. The embankment was for a settling basin forming a portion of the water purification works at Columbus, O. These works occupy a rectangular tract 500x700 ft. in area and the spoil and the materials for construction were largely handled by two Lidgerwood traveling cableways of 760 ft. span. One of these cableways was turned

to the novel duty of operating the roller on the embankment slope. The settling basin was lined with 18 ins. of 2 parts gravel and 1 part clay puddle mixed in a Drake continuous mixer. The puddle was deposited in 6-in. layers, each of which was allowed to dry and was thoroughly rolled before the next layer was placed. For rolling the puddle on the bottom of the reservoir a 5-ton grooved roller made by the Kelly-Springfield Co., was used. The embankment slopes were, however, too steep to permit a steam roller being operated and, therefore, use was made for this task of a home-made roller operated by one of the cableways. The roller

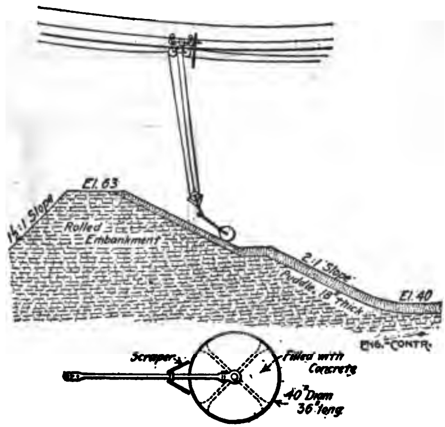


Fig. 19. Method of Rolling Reservoir Embankment.

was made from two 40-in. diameter fly wheels set close end to end on a common shaft and filled inside with concrete. This roller weighed 1,350 lbs. and was readily operated laterally up and down the slope or longitudinally up the slope. The whole arrangement proved very successful.

A roller, weighing 5 tons and drawn by a portable hoisting engine, was used for rolling slopes of reservoirs at Denver, Colo. (*Transactions, American Society Civil Engineers,* Vol. 27.) This machine is illustrated in Fig. 20.

Self-Loading Wagon for Building Reservoir Embankment. *Engineering and Contracting,* May 31, 1916, gives the following: In building embankment for the Hiland Avenue Reservoir at Pittsburgh, Pa., a novel device described by Emile Low was employed. This "home-made" machine consisted of a large box, supported by two pairs of wheels, and drawn by three horses. This box held about 1 cu. yd. At the front end there was a slat

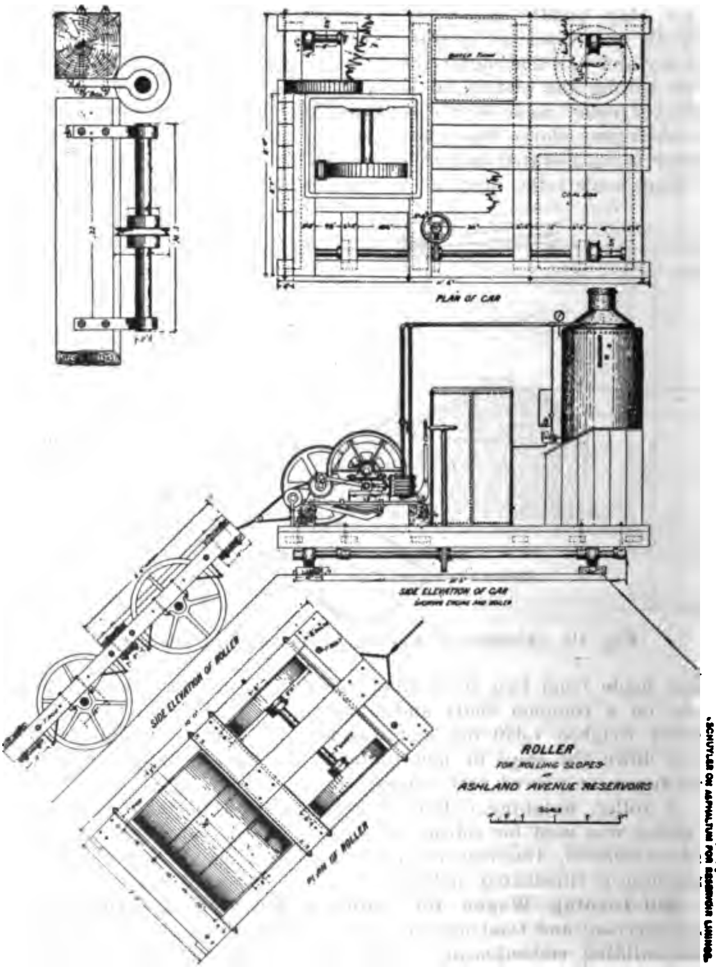


Fig. 20. Roller for Rolling Slopes.

elevator, operated by cogs and pinions. At the bottom of the elevator there was a scoop-shaped plow. The material was loosened by this plow and then forced upon the elevator and carried into the box. When the latter was full, the scoop or plow was raised and the whole machine was hauled to the embankment. The bottom of this box consisted of a number of hinged slats, which, when turned, allowed the material to drop out gradually, forming a layer of about 4 ins. Ths machine proved an ideal one for building the embankment, first on account of the thin and even layers deposited, and, second, on account of the consolidation of the layers by the passage of the heavy loads over it. Notwithstanding this, rolling with the prescribed heavy grooved roller was never omitted, although it seemed at times to be a senseless requirement.

Cost of Embankments and Puddle for a Settling Basin. *Engineering and Contracting*, June 25, 1913, gives the following relative to a settling basin for the Minneapolis filter plant: For building the embankment a selected clayey material was obtained from two borrow pits in the immediate vicinity and was hauled by means of common dump wagons of 1¼ cu. yds. capacity, or No. 2 wheel scrapers, as the length of haul demanded. This was spread in 6-in. layers, was well sprinkled and rolled by means of a 14-ton steam roller.

On the side of the raised embankment of the settling basin next to the water a puddle wall of selected clayey material 4 ft. thick was built. This puddle was placed in horizontal layers from 1 in. to 2 ins. thick. It was well sprinkled with water and tamped with wooden tampers until the whole was of the proper consistency and was then allowed to dry. Embankments and puddle wall were kept as near the same elevation as possible at all times. After placing the puddle wall and the embankments were at or near their proper heights, a layer of crushed limestone 14 ins. thick measured normal to the slope was placed thereon. On top of this, for a part of the slope distance, a 6-in. layer of 1 : 2 : 4 concrete was laid in 10-ft. strips with an asphalt joint between them. The remaining portion of the embankments were covered with sandstone paving stones taken from the north basin which were of no further use there. All inside slopes have a slope of 1 : 2, and all outside slopes 1 to 1½.

Labor Cost Data on Settling Basin for 1911. Earth Fill. The earth fill was well sprinkled with water and was rolled in 6-in. layers with a 14-ton steam roller. The average unit cost on 16,212 cu. yds. of fill was 48.5 cts. per cu. yd. The average haul was 1,200 ft. Amount hand-tamped, 1,100 cu. yds.

Puddle Wall.—Earth hand tamped in 1½ to 2-in. layers. Water

pumped with hand pump. The average unit cost on 836 cu. yds. was 89.2 cts.

Laborers were paid $2.25 per day; and teams $4.72 per day.

Labor Cost Data on Settling Basin in 1912. Earthwork.—Excavation: 321 cu. yds. of earth were excavated from trenches by hand at an average cost of 78.4 cts. per cu. yd. This cost includes the sheeting and staging. Of the 321 cu. yds. excavated, 236 cu. yds. was dry work, shoveled three times, 40 cu. yds. was wet clay handled four times, and 45 cu. yds. was wet clay handled twice, at average costs of 80 cts., $1, and 40 cts. per cu. yd., respectively. Backfill: 747 cu. yds. were backfilled by hand and scraper at an average cost of 34.7 cts. per cu. yd. The ground was wet and partly frozen. This figure includes the hauling of 93 cu. yds. 900 ft. Fill: The fill of 10,773 cu. yds. was well sprinkled and rolled in layers of 6 ins. with a 14-ton roller. Average cost, 49.8 cts. per cu. yd.

Puddle Wall.—The 1,529 cu. yds. of puddle were tamped by hand in 1½ to 2-in. layers at an average cost of 75.7 cts. per cu. yd. The water needed was pumped by hand.

Laborers were paid $2.40 per day, and teams $5.00 per day.

Labor Cost Data on Filters and Filter House in 1912. Earthwork.—Excavation: 2,409 cu. yds. of clay was excavated with pick and shovel at average cost of 65.2 cts. per cu. yd. Some of this clay was handled three times. The cost includes a small amount of sheeting. Fill: 6,494 cu. yds. of fill was made at an average cost of 44½ cts. per cu. yd. Sandy soil was used and was tamped by hand under pipes. The average haul of material was 800 ft.

Earth Dam at Springfield, Mass. Charles R. Gow in *Engineering and Contracting*, Jan. 18, 1911, gives the following: A dam for the Springfield (Mass.) Waterworks was 740 ft. long at the crest and its maximum height above the natural ground was 35 ft. Its maximum width at ground level was 165 ft. The slopes were carried 1 on 2 and a roadway 16 ft. wide surmounted its top. A cut-off trench was carried to rock for the entire length, in which was built a concrete cut-off wall 3 ft. thick, extending upward from the ledge to a little above the natural surface. Surrounding this cut-off wall and extending upward through the middle portion of the cross-section is a clay core built with the material secured from the borrow pit.

As practically all of the excavated material was to be utilized in fills, either in the earth dam or in grading over and around the completed filters, no satisfactory system of car transportation for the excavated material was deemed available. Two-horse teams hauling bottom-dump wagons were used throughout the work, and the excavated material was deposited without further

rehandling in its final position. The elevation of filter subgrade was 455, while that of the finished dam was 495, necessitating a final maximum uphill haul of 40 ft.

Snatching the Wagons Uphill. A short, steep road was selected up the side hill at the westerly end of the dam and an 18-in. gage railway track laid in a straight line from the bottom to the top of this road. A hoisting engine was installed at the top of this track and a weighted car, consisting of a small steel tank filled with concrete and mounted on four wheels, was operated up and down the track by this engine with a cable. The top of this car was just high enough to catch the rear axle of the wagons. In operation the teams drove on to and over the track near its

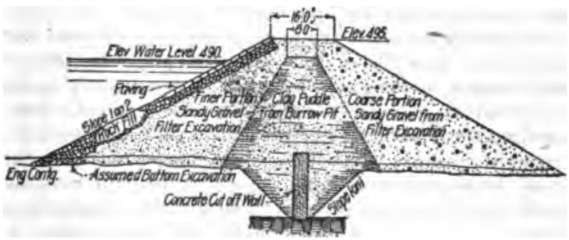


Fig. 21. Settling Basin Dam, Springfield, Mass.

lower end and headed uphill with the wheels astride the track, the car at this time being at the lower extremity of the railway. The car was then started up the track, catching against the rear axle of the wagon, and practically boosted the load uphill, the horses being only required to keep the pole headed in the proper direction. At the top of the track the team swung off downhill toward the fill, and the car ran back by gravity to await the next load. The grade of this road was about 18% and its length about 150 ft. The teams could be handled on it at the rate of one per minute.

General Excavation. The item of General Excavation included all excavation for the filters, for the aërator and various building foundations, for stripping at the site of the dike, and in general all cases of earth excavation required under the contract in which the depth of the excavation was less than its breadth. The total amount of yardage included under this item was 56,147 cu. yds., of which 45,081 cu. yds. were handled by steam shovel and 11,066 by hand loading.

The excavation for the filters was handled for the most part by a steam shovel, while all other General Excavation, including a small amount in the filters, was excavated and loaded by hand

labor. The cost records were so kept as to only designate between these two methods.

Thew Shovel Work. A No. 1 Thew steam shovel with a 1¼-yd. dipper was selected for excavating the filter beds because a large part of the work consisted in very light cuts. It worked well on the first two filters, maintaining an output of from 300 to 500 cu. yds. per day.

When excavation for the third filter was reached, many large boulders were encountered, and from that point onward their occurrence became general. The work of excavation now became most tedious and expensive. The shovel, although not dsigned for such work, was able to dislodge many of the small boulders of 1 cu. yd. or less, but a large percentage were of such size as to require blasting before the shovel could proceed. The delays incident to meeting these obstructions frequently reduced the daily average to less than 100 cu. yds. In some places boulders were so thickly grouped in the ground that it was necessary to resort to hand excavation to clear around and remove them. The gravel surrounding the boulders was cemented to such an extent as almost to resemble concrete. Attempts were made to blast the bank ahead of the shovel, but it was impossible to drill into the material with any degree of success. The ground contained so large a percentage of stone, both large and small, that neither a churn drill nor a steam drill could be put down without its course being deflected. There remained nothing to do but to scratch away the gravel from around the boulders and pry them out with the dipper or otherwise to blast them. Added to the frequent delays from boulders, breakdowns of the shovel due to the excessive strain upon it occurred almost daily.

The cost of steam shovel filter excavation, including that of teaming it to its disposal point was as follows for 45,080 cu. yds.:

Delivering and installing shovel	$0.011
Foreman supervising excavation	0.037
Shovel operation, labor	0.047
Coal, oil, etc	0.033
Total	$0.08
Repairs, labor	0.007
Repairs, materials	0.014
Total	$0.021
Depreciation on shovel	0.039
Teaming excavated material	0.215
General expense, 12.9%	0.052
Grand total per cu. yd	$0.455

The cost of installing the shovel includes the expense of four sections of oak platform, each section being 12 ft. long by 5 ft.

wide and 4 ins. thick. Each section was fitted with lifting rings so that it could be easily handled by the dipper of the shovel and transferred from the rear to front as the shovel moved forward.

No dumping expense is charged in the teaming item, as all labor of that nature is included in the cost of the embankment.

Hand Excavation. Eleven thousand and sixty-six cu. yds. of General Excavation was loaded by hand methods. A small amount of loam stripping over the filter site was done with wheel scrapers. Much of the area to be stripped, however, was of a marshy nature, due to the presence of springs at the upper end of the lot. This rendered the soil so soft as to prohibit the working of horses over it. Other parts of the lot were so stony under the surface as continually to stall the scrapers, and the scraper method of excavation was finally abandoned and wagons and shovels substituted therefor.

The permanent diversion of the brook required about 1,200 cu. yds. of excavation, which was executed entirely by hand methods. Part of this channel was quite deep and required some staging and rehandling for the bottom part.

Excavation for the office and laboratory building, for the regular house and for the aërator were carried to depths of 7, 9 and 7 ft. respectively. The material in this excavation was cemented sand and gravel, requiring loosening with picks but without the presence of boulders.

The removal of all soil covering the area of the dam site and the first 4 ft. in depth of the cut-off wall trench were also handled by hand. Excavation for central drains in each filter was also done by hand labor and was exceedingly difficult, being composed mostly of small boulders. The following figures give the average cost of the 11,066 cu. yds. of hand work.

Foreman	$0.037
Picking and shoveling	0.527
Miscellaneous supplies	0.005
Teaming	0.215
Total	$0.784
General expense, 12.9%	0.101
Total per cu. yd.	$0.885

Trench Excavation. Various pipes and drains in connection with the several parts of the work required 4,759 cu. yds. of trench excavation. Of this account, 653 cu. yds. were in the cut-off trench for the earth dam. In general, all excavations whose depth exceeded their width were classed as trench excavation. The excavation in the cut-off trench of the dam involved special

treatment and was subsequently handled and paid for as a separate proposition.

The average cut of the many pipe trenches was about 7 ft. and their average width at the bottom was approximately 4½ ft. The specifications provided that the measurement for payment should include slopes of 2 vertical to 1 horizontal, regardless of whether more or less was actually removed. The general nature of the material, however, was such as to allow vertical banks in all cases, mostly without boulders. The cost of this compact cemented sand and gravel trench work was as follows for 4,106 cu. yds.:

Picking and shoveling, inc. backfilling	$0.243
General expense, 12.9%	0.032
Total per cu. yd	$0.275

Blasting Borrowed Excavation. This item of the work embraced the securing and delivery of such material as was required for the fills in excess of that supplied from General Excavation. It was originally expected that Borrowed Excavation would only be necessary in supplying about 16,500 cu. yds. of clayey material for the core or middle portion of the earth dam. It subsequently became necessary to increase the amount of borrow to 30,000 cu. yds. on account of the deficiency of material caused by the elimination of boulders and large stones from the material brought from General Excavation.

Material conforming to the requirements of the specifications for use in the core of the dam was obtained on land belonging to the city, at a distance of approximately 2,500 ft. from the dam in an uphill direction. The haul from this point to the dam was, therefore, downhill to the filter site, from which it was necessary to haul up grade as the dam fill increased.

The material was a compact, clayey sand, containing at times a moderate amount of gravel. Its location in a side hill afforded an excellent opportunity for loading, and eventually a face of 50 ft. in height was obtained.

An attempt was made to loosen the material by blasting, using black powder in holes drilled some distance back from the face. It was found, however, that water seeping through the material wet the holes, and even when not troubled from water the shots were unsatisfactory, due mainly to the elastic nature of the material.

An attempt was then made to loosen a large section of the bank by means of a tunnel driven into the hill and exploding a mine therein. Again the result was unsatisfactory, the effect of the shot manifesting itself in the shape of a small crater while only a comparatively small amount of material was loosened in pro-

portion to the amount of labor and explosives required. A successful method of loosening was finally obtained by the use of undercutting shots. A row of short holes was churned in diagonally downward along the base of the vertical face of the pit. These holes were fired simultaneously, using dynamite for the purpose. The resulting shot kicked out a triangular strip of the material from under the face, while the shock of the explosion caused the overhanging mass above to crack and topple over, thereby breaking it into a loose pile which was easily shoveled. At times, after the face had reached a considerable height, four or five holes loaded with 10 or 15 sticks of dynamite would loosen and break up from 100 to 150 cu. yds.

For loading the material into wagons a large guyed derrick was installed and equipped with a 1-yd. orange-peel bucket which delivered into a hopper under which the teams drove and received their loads. This arrangement was very satisfactory while working, but the frequent delays caused by minor breakdowns and repairs rendered it uneconomical.

Wagon Hauling. The average length of haul from the pit was about 2,500 ft., or a round trip of 5,000 ft. The greatest number of trips per team, made or required, was 20 in 10 hours. The average for the entire work was about 18. The wagons holding 1½ cu. yd. level measure were ordinarily well rounded up when leaving the pit, but the average load, bank measure, was only about 1 cu. yd.

The nature of the material rendered it difficult to team over during or immediately after wet weather, and the same was true of the highway over which the teams were obliged to pass. On the other hand, in dry weather, the highway was deep with dust, adding another unpleasant feature. The cost of 19,952 cu. yds. of clay borrowed for the core wall was:

Blasting:	
Labor drilling holes	$0.017
Explosives	0.018
Total cost of blasting per cu. yd	$0.035
Loading:	
Foreman, laborers, etc	$0.2022
Coal, oil, plant, etc	0.0226
Special tools used	0.0014
Total cost of loading per cu. yd	$0.226
Teaming to dam	0.36
General expense, 12.9%	0.08
Grand total per cu. yd	$0.701

Since double teams cost $6 per day, the teaming charge of $0.36 gives an average of 17 cu. yds. per team. It may be added

that but few teams could stand this work continuously, and frequent changes of teams were required to rest the horses.

Second Borrow Pit. When the filter excavation was completed it was found that additional material to the extent of several thousand yards would be required to complete the fills.

A borrow pit was accordingly designated by the engineer located near the tunnel portal at the westerly end of the work, an average distance of 1,400 ft. from the dam and 1,00 ft. from the general fill over and around the filters. The general level of the floor of this pit was somewhat higher than that of the finished dam, and at a slight expense a sidehill road was constructed, which permitted a practically level haul to this point. The steam shovel from the filter excavation was installed in this pit and worked under much more favorable conditions than it had met in the filter excavation. The material first encountered was of a compact, rough gravel, but this soon changed to a sandy clay which was used throughout the upper portion of the dam, both for core and outer fill. The cost of gravel and clay excavation in this pit and teaming to the fills was as follows for 16,296 cu. yds.:

Foreman	$0.022
Loading teams	0.084
Coal and oil	0.016
Total cost of loading per cu. yd.	$0.10
Moving shovel from filters	$0.004
Repairs on shovel	0.082
Total	$0.086
Teaming to fills	0.21
Constructing roads and bridges	0.012
General expense, 12.9%	0.055
Grand total per cu. yd.	$0.485

The cost of loading is somewhat misleading, since it includes the loading by hand of all soil stripping, a total of 2,330 loads out of 13,843 loads taken from the pit.

Spreading and Rolling the Embankment. After the area to be covered by the dam had been grubbed and stripped of soil, and after the cut-off wall was constructed, material from the borrow pit was dumped, spread by hand and tamped on both sides of the wall until its level reached that of the surrounding ground. From the ground level the fill was carried upward as indicated in Fig. 21, material from the filter excavation being dumped and spread on the two outside thirds and that of the clay borrow pit on the middle third. The several layers were so deposited that the clay and gravel lapped each other alternately at their joints, giving a dovetailed bond between the core and the main fill. The

specifications required that the layers should be carried 4 ins. thickness. This provision, however, was not rigidly insisted upon, the usual thickness being at least 6 ins., and at times even heavier layers were permitted if in the judgment of the engineer the material was of a nature to admit of proper consolidation by rolling. This feature is a most important factor in reducing cost, and must, therefore, be considered in connection with the cost figures herein given.

For a while the spreading was accomplished by means of a No. 2 Climax road machine drawn by two horses. The teams dumped the material in rows and the machine following level the rows to the required thickness. When the rough material was encountered in the filter excavation, it became impracticable to use the grader, as the large stones were so numerous that the machine was unable to spread the piles even when drawn by four horses. This necessitated recourse to hand-leveling and the use of a stone drag and teams to remove stones larger than 6 ins. in diameter which the specifications directed should be excluded from the fill. Small stones from 6 to 12 ins. in size were thrown down the slopes, those on the upstream side remaining there and constituting part of the 3-ft. rock fill called for on that slope, while stones thrown out on the downstream slope were collected and teamed to the crusher to be broken for use in concrete. All large stones were loaded on a drag and rolled into the rock fill.

The specifications provided for the rolling of the embankment with a grooved roller weighing not less than 1½ tons per linear foot of roll. This provision, of course, necessitated the use of a power roller. For a short time a traction engine weighing about 10 tons was used for the purpose and gave excellent results so far as the quality of rolling was concerned. It was out of commission so often, however, due to breakdowns and defects, that a new Buffalo-Pitts tandem type of steam roller was purchased and its two rolls equipped with heavy steel bands to give them the grooved effect. This roller was rated by the makers at 8 tons, but with its boiler and tank filled and the added weight of the steel bands it actually weighed 12 tons. This total weight of the roller produced the necessary load specified by the specifications on each of its two rolls, consequently every layer received two rollings every time the roller passed, each conforming to the specified requirements.

While awaiting the arrival of this roller, a horse roller weighing 2½ tons, or ½ ton to the linear foot of roll, was used and was drawn by four horses. This roller did not, of course, meet the contract requirements, but a temporary concession was made in the matter by the engineer during this interval. This same horse roller was later used near the top of the dam during a short

interval while the steam roller was undergoing repairs. It is estimated that from 8,000 to 10,000 cu. yds., or about 17%, of this embankment was rolled with this horse roller.

Considerable difficulty was encountered in rolling the clay core after a rainstorm, with the heavy roller. This material when once wet retained the moisture for a long period, and when saturated assumed a jelly-like consistency. On such occasions, layers of gravelly material were spread over it and rolled until the clay squeezed up through it. Sometimes several layers of gravel were required to stiffen the clayey material sufficiently.

As a general thing, the teams passed over the dam longitudinally with their loads, and it is highly probable that the grooving action of the wheels, together with the tamping action of the horses' hoofs, was of great assistance in consolidating the fill. Very little watering was required, as the material from the filter excavation was usually moist if not wet, and it was found difficult to wet the clay without softening it too much.

Material was measured in excavation and embankment and 11,000 cu. yds. of shrinkage discovered. Owing to different classes of fill for which excavation was used, it was not possible to say how much of the total shrinkage was due to the compacting of the embankment; however, this was estimated to have been 11%.

The cost of building this embankment, after delivering the earth, was as follows for 52,233 cu. yds. in place:

Labor and teams used in spreading material and picking stones	$0.0435
Labor making roads and bridges	0.001
Miscellaneous supplies	0.0005
Total for spreading in layers	$0.0450
Operating steam roller	0.0098
Coal, oil, etc.	0.0055
Depreciation and repairs on roller	0.017
Teams on horse roller	0.0076
Total cost of rolling per cu. yd.	$0.0399
Teams watering	0.0008
Foreman	0.0151
General expense, 12.9%	0.013
Grand total per cu. yd.	$0.1138

General Fill. The work embraced under this item included the fills around and over the filters, the grading and loaming of the same and all other fills around the grounds which might be made under the direction of the engineer.

The loam originally stripped from the filter site was the only earth rehandled under this item, representing perhaps 1,000 cu. yds. The balance of loam necessary to cover the various fills was paid for both as borrow and as general fill. With the exception

of the 1,000 cu. yds. of loam mentioned, the expense charged to this item was limited to that of dumping, spreading and grading material hauled from the excavations. The cost of 22,520 cu. yds. of general fill was as follows:

Labor dumping, spreading and grading	$0.0618
Teams and labor rehandling 1,000 cu. yds. of loam	0.0147
General expense, 12.9%	0.01
Total per cu. yd	$0.087

Comment on above figures: The total expense of rehandling 1,000 cu. yds. of loam is here divided into the entire yardage of the item. It actually cost about $0.33 per cu. yd. of loam rehandled, the average haul being about 500 ft. each way.

Clearing. Complete data on the cost of clearing and grubbing for this project will be found in Gillette's "Clearing and Grubbing."

Steam Shovels and Elevating Graders on the Belle Fourche Dam. *Engineering and Contracting,* Oct. 7, 1908, gives the following unit costs for part of the work on the Belle Fourche Dam that was built under contract. This dam is built across Owl Creek about 10 miles northeast of Belle Fourche, So. Dak. It is 115 ft. high and 6,200 ft. along the top.

The contract was let in Nov., 1905. After placing about one-third of the fill, the contractor made an assignment and the work was taken over by the government.

Borings and test pits at the dam site show that the material is homogeneous and compact. An analysis of the earth to be used in the dam was made, and from this the location of the borrow pits determined. The material is an adobe clay, very sticky and boggy when saturated, but bakes very hard when dry, and it is hard to plow. There are occasional layers of sand and shale and scattering cobble stones. The clay is readily compacted and is nearly impervious to water.

The dam is built in 6-in. layers and all stones larger than 6 ins. in diameter are excluded. Neither a core or puddle wall is used in the embankment or dike. There are 1,580,000 cu. yds. in the finished embankment.

Sprinkling. The fact that Owl Creek runs dry in summer made it necessary for the contractor to store water for use in compacting the earth. A reservoir was built, at his own expense, at each end of the dam. Into these reservoirs water was pumped from the creek during the rainy period. The rate of evaporation being high, much more water than actually needed for compacting has had to be stored. The sprinkling was done with hose connected on the elaborate system of pipes, laid on top of the dam. When there was water in the creek the water was pumped di-

rectly into the system of pipes, but when the creek was dry the reserved supply in the reservoirs was used. Any leaks in the pipes caused troublesome bogs, as the adobe clay absorbs water quickly. On the other hand, when dry, it pulverized easily, thus causing great clouds of dust on windy days. Although the work was not interfered with on account of rain, it had to be suspended during these wind storms, as neither man nor beast could stand the dust. This dust so affects horses and mules employed on the reclamation service that many of them get a lung trouble from which they quickly die. The aridity increases the cost of sprinkling.

Another condition that affected the cost of the work was that the surface water was so bad for boilers that the contractor was compelled to put down two artesian wells, each 1,430 ft., to supply water for his steam shovels, locomotives, traction engines, rollers, etc. For about four months in the year the work on the earthen dikes had to be shut down, owing to the cold weather, as the material would freeze in the embankment. All trench excavation, excavation for structures, for stripping borrow and gravel pits, and for trimming embankments, were paid for extra.

Amount of Work. The costs below include the cost of the work done by the contractor during the years 1906 and 1907, a total of 504,000 cu. yds. Two methods were used in this work; one being steam shovels and trains, moving 305,000 cu. yds.; while the other was by elevating graders and wagons, excavating 199,000 cu. yds. In 1906 one steam shovel was used, while in 1907 two shovels were worked.

Cost of Outfit. The outfit and the value of it used on the work was as follows:

2 (75-ton) Vulcan steam shovels	$22,000
6 (18-ton) Davenport dinkeys, at $3,100	18,600
40 Western 4-yd. dump cars, at $230	9,200
2 Standard Western graders, at $1,200	2,400
4 (32-hp. 21-ton traction engines, at $3,500	14,000
1 (12-ton) Kelly Springfield roller	2,500
4 Miles of track complete	16,000
2 (6-horse) road machines, $225	450
24 (1½-yd.) Aurora wagons, $120	2,880
15 Buck scrapers, $17.50	263
Pumps, pipe, camp, miscellaneous tools, etc. (est.)	11,707
Total plant	$100,000

This is the plant that was on the work at the end of 1907, but not much more than half of it was on the work during 1906; hence, if we figure interest, depreciation and repairs at 2% per month, we have $12,000 for 1906 and $24,000 for 1907, or a total of $36,000 for the two years.

Steam Shovel Work. The method of carrying on the steam shovel work was as follows: Two 75-ton Vulcan steam shovels equipped with 2½-yd. dippers loaded dirt into 4-yd. Western

dump cars. A train of 10 cars were pulled on 3-ft. gage tracks by 18-ton Davenport dinkeys. Two dinkeys pulled the trains for each shovel and an extra dinkey spotted cars. The cars hauled 3.1 cu. yds. place measurement, as determined by 100,000 loads. During 1906, the material was hauled an average distance of 1 mile against a 2% grade, while in 1907 the 1-mile haul was all down grade, the maximum grade being 4%.

Spreading. The tracks on the embankments were so arranged that earth was spread 50 ft. each way from the track. The layers were made 6 ins. deep. As the dumping of the whole train of 10 cars at one time would result in the earth blocking the movement of the cars, only alternate cars were dumped, and then the train was pulled ahead a train length and the other five cars dumped. As the cars when coupled measured 13 ft., center to center, this meant a pile of earth containing 3.1 cu. yds. every 26 ft. Each pile spread made about 138 sq. ft. of embankment 6 ins. thick. The idea of dumping alternate cars is excellent on embankments of this character, or even in widening railroad embankments, as it makes the spreading of the material easier.

At first the attempt was made to spread these piles of earth with a Western Embankment Spreader, but the dinkeys were not powerful enough to handle the spreader against the piles of earth. This spreader will spread the earth about 7 ft. from the rail, so, if it had worked successfully, the area it could cover would have been enough to spread out the pile of earth to a thickness of 6 ins.

Six-horse road machines were then tried, but they, too, proved a failure when used alone. The reason for this was that the material when excavated by the steam shovel came out at times in large clods or lumps, and these lumps tossed the machine around as the waves of the sea would toss a small boat. Recourse was then had to buck scrapers to do the preliminary spreading. These pulled by horses spread the earth out roughly for a distance of 50 ft. on each side of the track, the road machine finishing off the layers. Three layers were thus spread before the track was shifted into a new position, 10 ft. from its old place.

The sprinkling was done from the system of pipes run over the reservoir dike.

The rolling was done by a 32-hp., 21-ton traction engine and a 12-ton Kelly Springfield road roller. The great weight of the engine no doubt was an assistance in compacting, but unless the tread of the driving wheels of the engine were wider than the standard, the area compacted by one trip of the engine could not compare to that of the roller. This would increase the cost of the rolling over using a roller of the same weight.

Wages. A 10-hr. day was worked by the contractor, and, owing

to the great amount of construction work going on in all parts of the country at that time, the labor was very indifferent. The shovel men and train crews were paid standard wages, while the laborers were paid at the rate of $2.25 to $2.50 per day. Horses were paid for at the rate of $1.15 per day. This cost covers the care and feed of the horse, likewise the interest and depreciation on the animal, and explains why horses are not listed under the head of outfit. Coal cost delivered on the work $10.50 per ton, 40% dynamite by the car load, 12¼ cts., and black blasting powder $1.20 per keg.

Cost of Work. The cost of the work, consisting of the total pay rolls, the cost of supplies and estimated interest, depreciation and repairs, was as follows:

Labor	$71,163.44
Supplies	22,827.08
Interest, depreciation and repairs (estimated)	30,000.00
Total	$123,990.52

This cost includes superintendence, camp expense, general expense, and, in fact, all direct and indirect cost of doing the work. The overhead charges were about 10% of the total cost. This cost is distributed over the unit costs given below.

The steam shovels excavated per day an average of 951 cu. yds., which is an excellent record to maintain for so long a period. The cost of supplying the water for engines and sprinkling has been included in the items given and in the unit costs given below, has been properly distributed. The cost per cu. yd. was as follows:

Excavation:	
Labor	$0.047
Supplies	0.027
Total excavation	0.074
Hauling:	
Labor on train	$0.037
Labor on track	0.012
Supplies	0.035
Total hauling	$0.084
Spreading:	
Labor	$0.118
Rolling:	
Labor	$0.006
Supplies	0.007
Total spreading	0.013
Sprinkling:	
Labor	$0.014
Supplies	0.004
Total sprinkling	$0.018

Plant:	
Interest, depreciation and repairs (estimated)..........	$0.098
Grand total	$0.405

Spreading Earth. This is a high cost for earth excavation of this class, even under the adverse conditions under which the work has been done. This cost is among the highest for earthen embankments for reservoirs so far built by the Reclamation service. The high price of coal has added to the cost of loading, hauling, and compacting, but a glance at the unit cost shows that the spreading of the earth on the embankment was too costly. One of the high officials of the Reclamation Service stated that the contractors on this work lost money, having been hampered by a shortage of funds and inefficient superintendents. The contract price for the embankment was 28 cts. per cu. yd. so about 12 cts. per cu. yd. was lost on this part of the work. The spreading cost about 12 cts. It should have been evident to any one that such a cost was ruinous, as this work on reservoir construction seldom costs more than 2 cts. per cu. yd.

On the upper Deer Flat embankment, on the Payette-Boise project, an embankment of about 1,000,000 cu. yds. was built with cars and steam shovels and the cost was less than 2 cts. per yd. for spreading. Here the track was moved away from the earth, after the cars were dumped, with teams of heavy horses, when road machines did the spreading, two machines spreading about 300 cu. yds. per hour. The track lies flat on the ground, and is well spiked to 6x8 ties. It stands the rough usage very well. The total cost for this spreading work up to 1908 was 1.9 cts. per cu. yd., although in some months the cost had been as low as 1.4 cts.

It is true that at the Upper Deer Flat embankment the earth was free from large clods, but even if the clods that hampered the work at Belle Fourche had been broken up by men with sledges or mauls, so as to make it possible for the road machines to do the spreading, the extra cost for breaking the clods would not have amounted to more than a cent or two per cu. yd., and it would have been less than that had they used a spiked disc harrow.

Elevating Grader Work and Hauling. Two Western Standard elevating graders were used on the work, propelled either by 16 horses or 21-ton traction engines. As a rule the engine is the cheaper method. These graders loaded Aurora dump wagons, having a capacity of 1½ cu. yds. The load, place measurement, actually carried was 11 cu. yds., as derived from a record of 100,000 loads. Three horses were used on these wagons, 24 wagons being used to serve the two graders, the average haul

being about 1,300 ft. The use of three horses to a wagon is to be commended. The extra cost is entirely in the horse, which in this case amounted to $1.15 per day, and the larger load carried with the other expenses of the work fixed, means that the extra cost of the horse is soon paid. With only 2 horses, either the load would not have been as large, the number of trips would have been reduced, or smaller and less loads would have been hauled. As it was, each wagon averaged about 42 trips per day, traveling a distance over the lead of about 10 miles. Considering the distance covered in following the grader and in turning, no doubt the total distance traveled per day would equal 15 miles.

The elevating grader, to a great extent, pulverizes the earth as it excavates it, hence in spreading no trouble was experienced with clods or lumps. This allowed the road machine to do the spreading without assistance, which confirms our statement that some form of clod breaker would have easily solved the problem of disposing of the clods that came from the steam shovel work. The sprinkling and rolling was done as described under steam shovel work.

The wages paid for men and horses are given above, also the cost of coal and other supplies.

The Cost of Grader Work. The total cost of the elevating grader work was:

Labor	$41,530.92
Supplies	4,468.24
Interest, depreciation and repairs (estimated)	6,000.00
Total	$51,999.12

This includes all costs, direct and indirect. The superintendence and overhead charges were about 12% of the total. Each grader loaded 556 cu. yds. per day. The road machine spread about 150 cu. yds. per hour.

The cost per cu. yd. of the grader work was as follows:

Excavating:	
Labor	$0.047
Supplies	0.012
Total excavating	$0.059
Hauling:	
Labor	$0.126
Spreading:	
Labor	$0.016
Rolling:	
Labor	$0.008
Supplies	0.008
Total rolling	$0.016

Sprinkling:	
Labor	$0.011
Supplies	0.003
Total sprinkling	$0.014
Plant:	
Interest, depreciation and repairs (estimated)	$0.030
Grand total	$0.261

It will be noticed that the spreading in this case cost 1.6 cts. The wagons deposited the loads 9 ft. apart in windrows 7 ft. apart, and the road machine spread it from these piles. This is real spreading, while in the case of the steam shovels the "spreading" consisted first of rehandling and then spreading. It is possible to spread earth very evenly with buck or Fresno scrapers, so that no other work on it is necessary.

The Cold Springs Earth Dam, Oregon. D. C. Henry in *Engineering and Contracting*, May 24, 1911, gives the following:

The Cold Spring Dam is part of the works of the Umatilla project of the United States Reclamation Service. The principal dimensions of the dam are:

Greatest height above bottom of creek channel, ft.	99
Height above valley bottom, ft.	88
Width of valley on center line of dam, ft.	400
Length of crest of dam, ft.	3,800
Top width, ft.	20
Length of spillway, ft.	330
Up-stream slope	3:1
Down-stream slope	2:1
Total volume of dam, cu. yds.	673,200

Available Material for Dam Construction. There were available within reasonable distance, the following classes of material: (1) Basaltic rock, hard and sound, readily blasted, and quite suitable for rip-rap; (2) gravel in deep hillside deposits on the north side of the canyon, ½ mile below the dam; (3) fine sandy loam, most readily available in any direction, for use in the embankment; (4) pure volcanic ash, in occasional strata and in small quantities; (5) indurated clay deposits, principally at the north end of the dam, and limited in area; (6) sand and gravel in deeper strata underlying the surface soil, and to some extent indurated.

The first three were the only materials that could be obtained in large quantities without extensive stripping. After study and experimentation with these materials, gravel was selected. Stability was secured by the use of gravel throughout the entire section of the dam; water tightness by an admixture of fine subsoil in the upstream portion; and perfect drainage by the use of unmixed gravel in the downstream portion.

The cut-off trench across the bottom of the canyon is 2 ft. deep and 30 ft. wide at its connection with bed rock. It reduces in depth and width up the hillsides until it is 6 ft. deep and has a bottom width of 10 ft. at the ends of the dam. To retard the flow along the plane of contact with bed rock a thin cut-off wall, 7 ft. high, was constructed on the center line of the trench, across the canyon, reducing in height up the side hill. Five additional walls were built on the north hillside where the rock was exposed.

Provision was made for drainage by a gravel-filled trench along the entire downstream toe of the dam with tile drain, and a network of additional trenches under the high portion of the dam, consisting of a parallel trench 120 ft. up stream from the water toe, with cross trenches every 100 ft.

Method of Construction. The design called for the handling of approximately 490,000 cu. yds. of gravel from the gravel pit in the north canyon side, about ½ mile below the dam, for the excavation of 191,000 cu. yds. of loam or subsoil, to be obtained mostly from the slopes within the reservoir, and for about 36,000 cu. yds. of rock pitching, to be placed on both slopes.

The gravel was excavated with a 70-ton, Model No. 60, Marion steam shovel, with 2½ cu. yd. bucket. The rolling stock consisted of fifty 4-yd. side-dump cars and five 16-ton American locomotives running on a 3-ft. gage track of 35-lb. rails. The average distance of gravel haul was 2¼ miles and the maximum grade was 1¼%. The gravel in the pit rose to from 30 to 60 ft. above the shovel and was in places overlain with considerable soil, rendering it necessary to watch the proportions of soil and gravel as they came on the cars to the dump.

The shovel was served by four gravel trains of from 9 to 12 cars each, which handled on an average, including moving and delays, about 1,600 cu. yds. per shift of 8 hours, the output per shift occasionally exceeding 2,200 cu. yds. The total rise from the steam shovel to the top of the dumping trestle was 65 ft., and the coal consumption per locomotive, for 1,149 shifts of 8 hours, averaged 2,400 lbs., coal being obtained from the Kemmerer mines in Wyoming.

The gravel was delivered on the dam by dumping from a trestle, 65 ft. high, built across the canyon, with its center line about 60 ft. down stream from and nearly parallel to the center line of the dam. The entire trestle came within the 100% of the gravel section, and the posts were left buried in the gravel, but all bracing was removed as the work progressed.

The fine subsoil or loam was obtained from various sources as follows:

From surface layers overlying the gravel in the gravel pit	100,000
From borrow-pits on the side-hill, up stream from the dam	108,600
From the feed canal and trenches	40,700
From the spillway channel	17,700
Tota. cu. yds	267,000

The loam from the gravel pit was handled in the same manner as the gravel. The loam from the borrow pits was handled by wheel scrapers up to distances of 500 ft. (22,300 cu. yds.), and by dump wagons loaded by an orange-peel excavator for greater distances up to 2,000 ft. (86,300 cu. yds.). The loam from other sources was moved by scrapers, only that portion excavated from trenches, etc., being used which was found suitable, the remainder being wasted.

Spreading and Rolling. The loam was delivered first, in its proper proportions, and spread by a road scraper, after which gravel was spread over it, being scraped by Fresno scrapers from the foot of the gravel dump near the trestle. The materials were mixed at first with disk harrows and subsequently with cultivators, the points of which scraped over and into the top of the previously mixed and rolled layer, after which the material was watered and rolled, producing a final layer of from 4 to 5 ins. compacted into a hard mass which required picking to excavate. Constant watch was kept of the thoroughness of the mixing process by excavating test pits. It was found impossible to secure complete mixing at all times. Unmixed gravel was nowhere found, but in some places fine streaks of loam had been left unmixed with gravel, in spite of every effort to avoid it.

The gravel in the 100% gravel section was not rolled to a large extent and was not watered. When the gravel dump had reached the height of the trestle, the track was raised by grading up until the full height of the dam was attained.

Riprap. The rock for slope pitching was obtained from the rocky basalt bluff on the north side of the canyon, a short distance below the dam. It broke up in fragments from 1 cu. ft. in volume down. A part of it was loaded by an orange-peel excavator, but most was handled from wheelbarrows into dump cars. It was hauled by rail, dumped on the slopes from the dump cars and sloped by hand. The total required was 36,000 cu yds. The construction of the auxiliary structures contained no elements of special interest.

The work on the installation of the plant was commenced in December, 1906. The first gravel was dumped in May, 1907, and the dam was completed on January 1, 1908.

Shrinkage. The design of the dam calls roughly for one-third

of the mass 100% gravel, one-third 50% gravel, and the remaining third 67, 75 and 80% gravel. Laboratory tests indicated a shrinkage of about 10% for the various mixtures, and from this it was figured that there would be required 490,000 cu. yds. of gravel and 191,000 cu. yds. of loam, or a total of 681,000 cu. yds., to make the 637,000 cu. yds. of compacted dam.

The actual quantity of gravel excavated corresponds closely to the estimate, but the quantity of soil handled was 76,000 cu. yds. in excess of that figured. This large excess must be principally attributed to the difficulty of keeping the soil and gravel apart in the gravel pit, and may be partly due to the occurrence of volcanic ash or dust in the delivered soil, which may not have assisted in swelling the quantities. The proportion of loam in the gravel, where it came unavoidably mixed with gravel from the gravel pit, may have been underestimated, and it is quite probable that much of the gravel, which from all appearances contained no soil, may have held proportions of from 5 to 10%. While the excess soil has added to the cost, it can hardly be deemed injurious as regards the drainage qualities of the gravel or its stability, and it has also added to its mass weight.

Cost. The total cost of the dam, arranged by its principal features, is shown in the following tabulation:

Main dam	$364,140
Auxiliary structures:	
Inlet works	16,140
Outlet works	19,710
Spillway	35,010
	$ 70,860
Preliminary engineering	5,000
Total, 49,000 acre-ft., at $8.98 per acre-ft.	$440,000

General administration, engineering and supervision, other than preliminary engineering, are included in the above figures.

The principal details of the cost of the main dam are as follows:

Embankment (yardage on basis of excavation measurement):	
Material from gravel pit: Gravel, 490,000 cu. yds.; earth, 100,000 cu. yds.; total, 590,000 cu. yds., at $0.385	$227,020
Material from borrow-pits, spillway and trenches:	
Earth, 86,300 cu. yds., orange-peel excavator, 36.1 cts.	31,120
80,700 cu. yds. wheel scraper at 19.4 cts.	15,630
Rip-rap —	
From quarry, 32,500 cu. yds. at $1.46	47,480
From trenches, 3,400 cu. yds. (charged to excavation).	

Excavation —	
Earth from trenches, spillway, etc., temporarily or permanently wasted, 34,400 cu. yds. at $0.293	10,060
Hardpan or loose rock, 6,600 cu. yds. at $1.37	9,020
Solid rock, 4,000 cu. yds. at $2.84	11,340
Concrete cut-off walls, 327 cu. yds. at $13.79	4,510
Drainage, including all work to July 1, 1910	7,960
Total	$364,140

A further analysis of the two principal items may be of interest:

Embankment: Material from gravel pit, 590,000 cu. yds.

Steam-shovel excavation: Rail haul, average distance 2¼ miles, average rise 65 ft.

Cts. per cubic yard, measured in excavation:

Steam shovel	3.6
Transportation:	
Railroad operation	5.5
Track maintenance	1.7
Total	7.2
Work on dam:	
Scraping, spreading and mixing	8.2
Sprinkling	0.2
Rolling	0.5
Water supply	0.7
Total	9.6
Plant depreciation	10.4
Plant maintenance	0.4
Total	10.8
Generai supplies	1.8
Camp shops, warehouses	1.2
Cleaning up, transfer of plant	0.6
Engineering, administration and general expenses	3.7
Grand total, cts. per cu. yd	38.5

Embankment: Material from borrow-pits, 86,300 cu. yds. orange-peel excavator, wagon haul, 500 to 2,000 ft.

Cts. per cubic yard, measured in excavation:

Excavation	13.1
Wagon haul	6.9
Sprinkling	0.4
Rolling	0.7
Water supply	0.8
Plant depreciation	8.5
Plant maintenance	0.4
Total	8.9
General supplies	1.1
Camp, shops and warehouses	1.2
Cleaning up, transfer of plant	0.5
Engineering, administration and general expenses	2.5
Grand total, cts. per cu. yd	36.1

The cost of gravel and earth for the main embankment, based on bank measurement, is higher than the foregoing figures indicate, by reason of heavy shrinkage, and is shown as follows:

Material from gravel pit, 590,000 cu. yds. at 38.5 cts...	$227,020
Material from borrow-pits, etc., 167,000 cu. yds. at 28.0 cts.	46,750
Total, 757,000 cu. yds. at 36.2 cts.	$273,770
Embankment measurement, 637,000 cu. yds. at 43.0 cts.	

The prices paid for labor per 8-hr. day and fuel were as follows

Common labor	$1.60 to $2.40
Teamsters	2.40 to 2.60
Teamsters, with team	4.50
Steam-shovel engine men	6.20
Cranesmen	4.00
Locomotive engine men	3.60
Carpenters	$3.60 to 4.00
Coal, per ton, on work	8.63

Construction of the Kachess Lake Dam. *Engineering News*, May 15, 1913, describes the construction of an earth dam 65 ft. high and 1,400 ft. long, built across the Kachess River in Washington by the United States Reclamation Service. The dam has a top width of 20 ft. The upstream slope is 3 to 1, the downstream slope 2 to 1. To prevent percolation a wide cut-off trench about 20 ft. deep was excavated parallel with the axis of the dam and from 20 to 60 ft. upstream from the center line. In the bottom of this trench a narrower trench was excavated to a depth of from 35 to 75 ft. below the original ground surface and in it a concrete core-wall, 2 ft. thick, was built, extending up to the original surface of the ground. See Fig. 22.

Cutoff Trench. The wide cutoff trench was excavated with teams and the drag-line excavator. The portion west of dam conduit was done wholly with teams and was pushed to permit the starting of the core-wall trench. The higher portion of the trench, east of the dam conduit, was done by teams. When water was encountered it was left for the excavator. The drag-line excavator deposited the material at the upstream toe of the dam, making an excellent footing for the riprap, also disposing of the material with one handling.

Deep Core-Wall Trench.—The excavation of the core-wall trench was commenced early in July, 1911, west of the dam conduit. The upper few feet were shoveled into wheelbarrows and wasted. Shafts were excavated ahead of adjacent portions of the trench, then the excavation was carried in horizontal benches about 7 ft. high. One or two men worked on each bench, loading the material into wheelbarrows, wheeling it along the bench to the side of the

shaft and dumping it into a vertical chute that carried the material to a wood bucket of ¾ cu. yd. capacity, heavily ironed and operated from the head frame. When filled, the bucket was hoisted to the head block, where a simple device dumped the muck into a 1½-cu. yd. car, in which it was hauled by one horse to waste dump. A double drum hoist was used which enabled two shafts to be worked by one hoisting engineer. This method allowed a number of men, working at different levels, on platforms laid on trench bracing, to work from each shaft.

It was intended to carry this trench to bed rock but the entire excavation was in such uniformly good material that it was considered unnecessary to go so deep. The maximum depth reached was near the westerly end which was carried to 75 ft. below the original ground surface. The material stood so well that generally the excavation could be carried about 10 ft. without sheeting.

As the core-wall was to be only 2 ft. thick, and it was difficult to carry the excavation narrower than 4 ft., the downstream side was carried true to line, so that the sheeting on that side could remain, and also to give room to remove the forms from the upstream side.

Material for the embankment was taken from a borrowpit 1,000 ft. from the east end of the dam.

A second borrowpit for loose material was opened 2,500 ft. from the east end of the dam.

Trestle. It was decided to depend on rolling to consolidate the dam, carrying material from the borrowpit in cars. A trestle 800 ft. long, of which 300 ft. averaged 60 ft. high, was built of sound timber saved from the clearing. Sawed timber was used for caps and stringers to save time of erection. The bents were 20 ft. apart, three posts to a bent. The trestle was located practically on the center line of the dam, with the base of rail at the proposed crest. It was double tracked with 30-lb. steel rails, 24-in. gage. A double track was laid to the borrow pit for tight material and a single track, with sufficient turnouts, to the borrowpit for loose material. From the west end of trestle a single track was extended about 300 ft. on a road-bed made with teams and beyond this point the material was hauled by teams.

Steam Shovel Work. While the trestle was being constructed, the borrowpits prepared and track laid, the cutoff and conduit trenches were backfilled. The hard work of filling in cramped quarters had been done the previous season. The steam shovel was moved to a 25-ft. bank of fine material just east of the outlet of the small conduit. Temporary tracks were laid and the filling was done by loading 1½-cu. yd. cars with steam shovels and hauling them by teams. The trenches contained some water.

The material was dumped, then worked into the water and puddled. When the fill got sufficiently dry to permit of using teams, the spreading was done with slips and fresnos.

About May 1 the trestle was ready for use, the shovel was moved to the borrowpit east of the dam and the construction of the embankment proper commenced. The pit had previously been cleared and some blasting done. The material from this pit was loaded into trains of 15 1½-cu. yd. side-dump cars, hauled by 9-ton steam locomotives. It was dumped from the upstream side of the trestle, falling to the ground below. At first the material fell inside the outer posts, but the addition of a deflecting apron 7 ft. long, covered with sheet iron, caused it to fall just outside the posts.

Spreading and Rolling. Spreading was done with fresnos of four-horse size, but usually drawn by three large horses or mules. It was found after the work became systematized that one fresno would distribute about 115 cu. yd. of the tight material in eight hours. The gravel or loose material was loaded by the drag-line excavator into a specially constructed hopper, of 40-cu. yd. capacity, mounted on skids for moving and fitted with two chutes and controlling gates, which enabled two cars to be loaded at a time. It was hauled in trains of twelve cars, dumped from the downstream side of the trestle and spread with four-horse fresnos. One fresno would spread from 150 to 175 cu. yd. of gravel in eight hours, the haul being much shorter than for the tight material and the gravel more easily loaded.

On account of the small working space of the embankment, difficulty was at first experienced in spreading the material as fast as it came in, but while the capacity of the machines was never taxed, a system was soon devised whereby it was kept pretty well cleaned up. About ten trains would be dumped in one pile, then another pile of ten train loads would be made, near the first pile, leaving only room for a roadway between, then a third pile adjacent to the second. While the second pile was being made, the first pile would be spread and stones picked from the second pile; then while cars were dumping on the third pile, the stones would be picked from it and the second pile spread. In this way there was no waiting and no confusion, the roller working on the area previously spread. The tight material occupied the upstream two-thirds of the dam (Fig. 22) and the gravel in the downstream third; it was handled in the same way except that it spread much easier, and the piles did not require plowing, which was necessary with the tight material, the impact from falling, particularly in the lower levels of the embankment, compacting this material very tightly.

The tight material was spread in 8-in. layers and all stones

exceeding 4 in. picked out, loaded into one-horse dump carts, and placed on the upstream slope. A road grader was on the work but the fresnos spread the material so evenly it was not used. The layer was then sprinkled by a 2-in. hose with ¾-in. nozzle, the amount of water varying greatly and depending on the weather and the material. The tendency at first was to use too much water, which produced a kneading motion in front of the roller. Carefully watching conditions and reducing the amount of water, sprinkling often with a rather fine spray, corrected this condition. The rolling was done with an ordinary 16½-ton traction engine. Extension rims on the driving wheels gave a rear wheel base of 56 in. Assuming that they carried two-thirds of the weight, the pressure per lin. in. was about 400 lbs. This engine

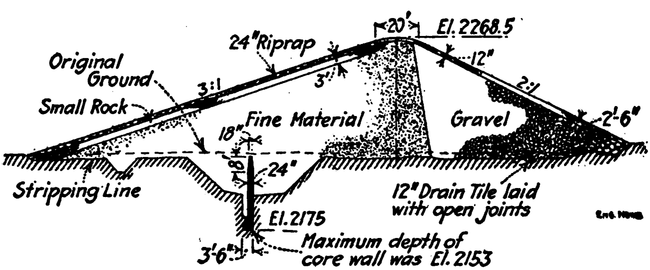


Fig. 22. Typical Section of Kachess Lake Dam.

seemed about the right weight for the materials and an excellent embankment was obtained.

It was found that the compacted layer was slightly less than 6 in. in thickness. Test pits were put down frequently and at predetermined points, in order to have a complete record of the behavior of the material, to determine whether or not the proper amount of water was being used, and, in general, to indicate whether there was anything to be guarded against or improved. No stratification was apparent; the only adverse criticism to be made was that certain layers that had been exposed to rain showed a little too much water.

The gravel was spread in a similar manner except that small stones were not so carefully picked out. The rolling was done by a grooved roller drawn by four horses and more water was used than on the upper side. The stones picked out were placed on the downstream slope. The junction of loose and tight material was approximately at the downstream posts of trestle bents.

Progress. To place the large amount of material in the short season available, the small area of the dump preventing the crowd-

ing of the machines, the shovel and embankment work was carried in two 8-hr. shifts, but as only half as much material was required from the excavator it only operated one shift. The best run of the shovel was 1,105 cu. yd. and of the excavator 1,000 cu. yd. in eight hours. The embankment was practically all placed in four months. All trestle bracing was taken out as the fill advanced, nothing being left in but the posts. When within 8 ft. of the top, the gravel portion was brought up about 6 ft., one track thrown on it, the balance of the trestle removed and the remainder of embankment completed.

The earthwork yardage was: Excavation, 550,000; embankment, 182,000; backfill, 32,000.

Drainage. A very complete drainage system was provided to lead off harmlessly any water that may find its way into the dam. At the downstream toe is a generous trench from 6 to 10 ft. wide at the bottom, extending the entire length of the dam, backfilled with stone, which filling is also carried some distance up the slope. From 30 to 60 ft. upstream from the toe is a 12-in. tile drain laid with open joints in a trench and surrounded with 2 ft. of small stone; this drain has frequent outlets to the main drain at the toe. Should water succeed in passing through the tight material, it will drop in the gravel portion, which contains practically no clay, and escape through the drains.

Constructing an Embankment for Hill View Reservoir, N. Y. The construction of the earth embankment for the Hill View Reservoir, New York City, is described by A. W. Tidd, in *Engineering News*, Sept. 9, 1915. The soil formation was a very dense, glacial drift, containing many stones and boulders but no ledge rock. The material was well graded from a coarse sand down to a very fine rock flour, excellent for a reservoir embankment. The sides of steam shovel cuts stood perpendicular for two years without change other than the scaling off caused by the action of frost.

The embankment was constructed of carefully selected and thoroughly compacted material, and backed up by the remainder of the excavated material, which equals and in many places exceeds in volume that of the especially treated portion. The embankment on the water side was rolled in layers not thicker than 4 in. when compacted, while in outer portion 2-ft. layers were allowed. This outer portion was formed of material unsuitable for the special impervious (4-in.) embankment.

The bonding of the base of the embankment with its foundation was done with extreme care. All unsuitable material was excavated and removed, and from the finally stripped surface, small boulders and all stumps and large roots were removed. Large firmly embedded boulders were allowed to remain if there was

room between them sufficient to operate the 10-ton steam rollers. Trenches were either backfilled by hand-ramming or sloped enough to allow the roller to ride into and across them. Earth was placed around the boulders and rammed until sufficiently mounded tò permit the roller to ride up onto them. The stripped surface under the base of the 4-in. embankment was thoroughly scarified, usually with a road plow, to a depth of 3 or 4 ins., and a thin layer of embankment material was deposited and rolled. An excellent bond was thus effected between the original and the fresh material, and this method was used throughout the entire construction of the embankment whenever work was started on an area that had lain untouched for a time. The 4-in. layers were then started, beginning in the lowest part, keeping the top of the embankment practically level.

The dumping areas were restricted, irregular in shape, disconnected, and often obstructed by boulders. As soon as possible, 3-ft.-gage track with 65- to 70-lb. rails were laid on the embankment and the material delivered in 4-yd., side-dumping cars, in 10-car trains, hauled by 10 to 15-ton locomotives. The tracks were laid in straight stretches as long as possible; and two parallel lines were used until the embankment became too narrow to accommodate them.

Spreading and Rolling. The trains were dumped in succession along the full length of the track and the material spread and leveled with a spreader-car into a layer about 6 ins. thick. As soon as the spreader-car had finished (usually in four trips) the track was pulled away a certain definite distance, lined up exactly parallel to the previous position, and was ready for trains again. The track was pulled into position by a track gang. The amount of the track throw was determined from careful observations taken on the compacted layers, for each layer, when spread, must just connect with the edge of the previously spread layer, and when rolled must be 4 ins. thick. The steamshovel runners became expert in loading the cars to the limit and at the same time with a very uniform volume. It was on that uniformity of volume that the success of the whole method depended. The system worked admirably. The track throw was in general 14 ft. The spreader-car was not able to spread the full width even when counterweighted, 10 ft. being about its limit, so the remainder was spread with a 4-horse road scraper. A stone gang worked continuously picking out and removing the boulders and stones larger than 3 in., in order to allow the roller to get onto the layer at the earliest possible moment. Here again the steam shovel runners coöperated by avoiding the larger boulders when loading for the 4-in. embankment.

Ten-ton rollers with grooved front wheel and cleated side wheels

were used. They were run back and forth parallel to the track, moving over the width of the side wheel about 18 ins. each trip, thus making four rollings on each layer. During hot weather the material required sprinkling to insure proper bonding and thorough compacting. The watering was done by an ordinary street sprinkling cart drawn by horses, and the water was applied to the roller layer before the new layer was dumped. A sprinkling car was tried, but given up, as it interfered with the regularity of the train movements. Some difficulty was experienced in securing thorough compacting wherever the direction of track shifting was reversed. In such cases it was necessary to place two layers one on top of the other before the track was shifted, and in the rush to take care of the material as fast as it was sent out from the steam shovels, great vigilance was required to insure that the proper amount of rolling was given the under layer. About 30% of the material was brought on in wagons. All spreading and leveling of the wagon dump was done with 4-horse road scrapers, after which it was rolled in the usual manner.

No settlement of the 4-in. embankment was ever detected, and from the evidence deduced from concrete structures built upon it and grade stakes given, the settlement must have been extremely slight, if any at all.

Dams of Boulder-Filled Wire Baskets. *Engineering News-Record*, Apr. 12, 1917, gives the following:

Hydraulic mining operations are now permitted in Western states only when there is some means of preventing the earth and rocks washed down by the jet from continuing on into the lower reaches of the stream. One way of accomplishing this is to build a dam across the stream just below the point where operations are under way. By this means there is formed a pool that serves the double purpose of providing a settling basin and capacity for storing the débris.

The margin of profit in such mining work is low; and where débris is to be retained by artificial pondage, only a dam that can be built at very low cost is feasible. Two dams have been built in California to meet this requirement. They consist of units, or baskets, of poultry netting filled with coarse gravel and rock. These units are 1 x 2 x 8 ft. in size and are placed lengthwise with the stream. They are built in place and are laid in the same way that shingles are placed on a roof, except that they are level instead of sloping. Each unit is made to lap over half of the preceding course.

As each course or layer is completed, sufficient backfilling is put in behind on the upstream side to give the structure a top width of 10 ft., in addition to the courses of netted units. The up-

stream side of the fill is kept at a slope of 1½ to 1, and the downstream slope ranges from 2 to 1 down to 4 to 1.

In making the units, common netting of 14-gage wire in 6-ft. widths is used. A 10-ft. length of this wire is cut from the roll and put in its place on the dam in a form composed of the last completed basket and a 2-in. plank set on edge and held in place by pins. Into the netting are then poured very coarse gravel and rock up to the size of a man's head. When a sufficient quantity has been deposited, the top is leveled off with a straightedge, and the selvage edges of the netting are drawn together by means of a piece of strap iron with a hooked end. The selvage edges are then fastened together with wire, and the ends are folded in and similarly fastened.

Construction Costs. On one of the dams of this type constructed for the Omega mine on Scotchman's Creek, California, the crew consisted of six men. Two men handled the netting, and four men shoveled and wheeled the material. This crew laid 20 baskets per day, a total of 320 cu. ft. They also placed the backfilling for this number of maskets, which brought up to 56.3 cu. yds. per day the total amount of material handled. At the rate of $3 per day per man the cost of labor and material in the entire dam was 48 cts. per cu. yd.

It is to be noticed that this work requires practically no equipment, calls for no initial investment in plant, requires no skilled labor, and, aside from inspection by state officials, only such supervision as a foreman can give. The only construction material that has to be shipped in is the netting.

The material placed in the baskets is the coarsest obtainable. The backfill is made of finer material; and as the dam increases in height and the upstream face is continually extended, effort is made to use finer and finer material so that the seal will eventually be complete and the upstream face of the dam as nearly water-tight as possible.

The fact that the downstream slope is made of very coarse material permits seepage to escape promptly, and thus internal pressure cannot occur. Another feature peculiar to this type of construction is that the height of the dam need not be predetermined and the structure can be continued indefinitely so far as the design and material are concerned.

Although the downstream face constitutes a cataract form of spillway over which the stream can quite safely be allowed to flow, the plan has been to provide a separate spillway for the dam when no further increase in height is desired.

The first dam of this type on the Pacific Coast was begun for the Omega mine in 1913, and has since been raised by slow stages

as the needs of the mine required. It had 43 layers and was about 43 ft. high in 1917. This dam is founded upon an old concrete dam about 50 ft. in height, the cost of enlarging which by adding more concrete was prohibitive. The second dam of the basket type was being built on Nelson Creek in Plumas County and had attained a height of about 26 ft.

Temporary Hydraulic Fill Dam Across Colorado River. *Engineering Record*, Dec. 25, 1915, gives the following:

For not quite a month, from Sept. 20 to Oct. 3, 1915, the entire flow of the Colorado River was diverted into the canal system of the Imperial Valley by a hydraulic fill dam, about 6 miles below Yuma. The unusual features of the work were the deposition of the dam-building material in the running water of the stream, and the fact that the material was obtained locally in a country notorious for the friable and unstable character of its soil — a soil commonly likened to sugar in its action when in contact with running water. However, the dam-building material was not this light alluvium, brought down by the ruddy Colorado, but heavier deposits pumped from below the present level of the stream bed.

Water for the irrigation of the valley, located in Southern California and the northern part of Lower California (Mexican territory) is taken from the Colorado River just above the international boundary line. This year the flow of the stream fell below the 7,000 average minimum, endangering the supply to the valley. The California Development Company, which owns the main canals in the valley and sells water to the mutual distributing companies, in order to save the crops determined to throw a dam across the stream just below its heading, thus diverting the entire flow into its canal, and wasting such water into the Salton Sea as might be in excess of its needs. For various reasons it was not possible, or at least not advisable, to put a permanent structure across the stream. The river is considered navigable by the War Department, and the cost of a permanent structure was out of the question because of the financial condition of the California Development Company. Furthermore, immediate relief was needed. It, therefore, was a problem of putting in a temporary structure, using such materials as were locally available.

While there is at the heading a good quarry, furnishing ample rock, previous ruling of the War Department, requiring a rock-filled trestle across the stream to be removed, barred such construction from consideration. Furthermore, a dam of that sort would have been costly, for experience in closing breaks in the Colorado has disclosed endless difficulties in building a pile trestle, the current washing the soft alluvium away from the piles with great rapidity.

Attention, therefore, was directed to some type of earth fill structure. Dry-earth handling methods were barred, because with them only the light alluvium could be economically secured. This is an unsuitable dam-building material because even the slowest current carries it away. Hydraulic-carriage methods were therefore resorted to, and were feasible only because beneath the present stream bed a considerable amount of heavier materials is to be found. These consist of stones up to 6 in. in maximum size and, principally, of a mixture of clay, alluvium and gravel, which when wet has considerable strength, and comes through a 10-in. dredge discharge pipe in lumps as large as 6 or 8 in. The theory was that these heavier materials discharged along the center line of the dam would build up a fairly good current-resistive core, the lighter materials being carried off by the separating action of the water to the upstream and downstream toes. Much of this material would be lost, but the larger particles and lumps would not be carried away by low current velocities. For the closure, which it was recognized would be the difficult part of the work, it was planned to make use of brush and sacks of earth.

Procedure. With the plan formulated, a 10-in. suction dredge, with a ladder and suction pipe long enough to reach to a depth of 15 ft. below the present stream bed, was put to work Aug. 12, 1915. The river at this point is about 900 ft. wide, and the dam makes an angle of about 10° with a line normal to the stream flow, the trend of the dam being downstream toward the right bank. The dredge in fourteen days carried the dam to an elevation of 12 ins. above water level, extending from the Arizona shore to within 250 ft. of the California shore. As the fill rose, light poles were jetted into it and quantities of willow and cottonwood brush piled against them to form a fence. There were two such lines, about 30 ft. apart, within which space materials were pumped to raise the crown of the dam rapidly. Three subsequent runs across the stream raised the dam to an elevation of 5 ft. above water level. With the type of construction described there resulted a base width of about 150 ft. and a crown of 30 ft., the depth of water being 6 to 7 ft. When the work was started the velocity of the current was from 2 to 3 ft. per second. As the channel cross-section was decreased the velocity naturally increased and at closure was about 6 ft.

Since the stream is subject to rapid rises and it was undesirable to take more than about 5,000 sec. ft. through the Imperial Valley canals, arrangements were made during the construction of the dam to cut it at two places. The ends of the dam, on each side of the point of final closures, were built as abutments, with brush and stick fences strengthened with sacks of earth, the lines being winged back along the toes. The same type of con-

struction was used at another point in the dam, thus making it possible by using light blasts to create quickly two 150-ft. channels.

Making the Closure. Before beginning the final closure the bottom was carefully lined with about 10,000 sacks filled with heavy material pumped by the dredge. The closure, which was made in a velocity of about 6 ft. per second, and at the very last instant in a depth of water of about 22 ft., was effected with the aid of cottonwood and willow-brush obtained on the river banks. The brush consisted of young trees, 6 to 10 in. in diameter at the butt, and 20 to 30 ft. long. These were piled on a barge moored upstream at the point of closure. Another barge was loaded with earth-filled sacks, while the dredge was in operation with its discharge line at the closure point. Two 1¼-in. steel cables were stretched from the California shore to the end of the dam beyond the closure point. The procedure was to throw the brush into the stream, butts pointing downstream, and so to guide them that the butts would come to rest against the cables. Bundles of brush weighted with sacks were thrown from the barge and, with the current, immediately brought pressure to bear on the brush, quickly bending the poles until at the steel cables they were pointed vertically upward. The strain on them was relieved by turning the discharge of the hydraulic dredge onto them. In this way progress was slowly made across the channel. Closure was effected on Sept. 20, when there was a head of about 6 ft. of water against the dam.

The structure remained intact from its completion until Oct. 3, when a rise of the stream, telegraphed ahead from Needles, 300 miles up the river, made it advisable to blow up the closure section. This was done by a charge of dynamite. During the time of complete closure the discharge went as low as 2,700 sec. ft., and on most of the days was about 3,500 sec. ft., all of which was needed in the valley. This was an exceptionally low stage of the river, particularly for a protracted period, though a minimum of 3,000 sec. ft. had previously been recorded.

Yardage and Costs. Yardage measurements of the prism indicate that there were 30,000 cu. yds. of material in the dam, though the pumping records, combined with observation of the percentage of material carried, indicated that 40,000 cu. yds. were pumped. The two figures are not inconsistent, because it is known that much of the fine material was washed to the toes and these lost. The costs for the pumping alone were as follows:

Labor	$578.38
Fuel oil (13,000 gal.)	416.00
Other oil, and supplies	100.00
Total	$1,094.38

On the basis of 40,000 cu. yds. pumped this would give a cost of 2.7 cts. per yd. The dredge was immediately upstream from the dam side, so that the length of pumping line was in no case greater than 500 ft.

For the final closure 450 cords of brush, at 73 cts. a cord; 21,300 sacks, at a total cost of $1,140, and 1,000 ft. of second-hand ¾-in. and 1¼-in. cable, at a cost of $100, were used. No timber or piling was bought, poles and brush being secured on the banks.

The total cost of the work was as follows:

Earthwork (dredge)	$1,100
Brush and poles	333
Sacks	1,140
Wire	32
Cable and clamps	100
All labor	2,000
Total	$4,705
Add 10% for supervision	470
Grand total	$5,175

As against this cost should be set the increased revenue of from $700 to $1,200 per day from the sale of the water.

Since low flows are to be expected and are likely annually to embarrass the irrigation district, the California Development Company plans to lengthen the ladder on its dredge in order to get deeper than at present. By so doing still heavier material will be secured and will enable a structure stable under even higher velocities than were experienced this summer to be built.

It is expected that the present structure will in part be carried out by high water, but that a considerable base will be left as a foundation for a similar structure next year, should that prove necessary. The dredge, of course, has excavated a deep and extensive hole which, it is expected, will be filled with heavy material brought down in the freshets of the next high-water season.

Cost of an Earth Embankment and Gravel Facing. The following data, taken from *Engineering and Contracting*, Aug. 12, 1908, relate to the construction of the Whalen earth dike by the U. S. Reclamation Service. This dike is located at the right extremity of the Whalen concrete diversion weir and extends to the bluff of the valley. This dike, together with the concrete diversion weir abutting onto it, furnishes a means of diverting the flow of the North Platte river into the Interstate Canal, and will serve that purpose for the Fort Laramie Canal when it is constructed. The dike is about 1,600 ft. in length, 11 ft. wide on top, with an average height of 10 ft. and side slopes of 2½ to 1.

The embankment contains about 35,000 cu. yds. of earth. The earth for its construction was taken from a borrowpit, the nearer

edge of the borrowpit being not less than 100 ft. and the outside edge at about 500 ft. The whole embankment is faced with a covering of gravel, the thickness on the top and downstream slope being 1 ft. and that on the upstream slope 2 ft. Practically the entire embankment was covered with gravel, involving the placing of about 6,040 cu. yds. of gravel. The distance from the gravel pit to the south end of the dike was 1,700 ft. on a down grade of approximately 1% from the pit and the total average haul was about 2,620 ft. The free haul under the specification requirements was 500 ft.

The earth body of the embankment was placed in layers varying from 6 to 12 ins. in thickness, and these layers spread by hand and thoroughly compacted by the passage of the scrapers and teams over them. The material as excavated shrank about 20% through the compacting to which it was subjected in being placed in the embankment.

The gravel facing was loaded with wheel scrapers through a trap into four-horse wagons with slat bottoms, each holding about 2½ cu. yds. The gravel was dumped from the wagons onto the embankment, and spread on the slopes by means of a Fresno scraper and a hand shovel. Foremen were paid from 35 cts. to 40 cts. an hour; laborers from 22½ cts. to 25 cts. an hour. The labor of horses in the earth work has been rated at 10 cts. an hour, and in the gravel work two-horse teams with drivers at from 40 cts. to 45 cts. an hour; three-horse teams with drivers, at from 50 cts. to 55 cts. an hour, and four-horse teams with drivers at from 60 cts. to 65 cts. an hour.

The cost of the 35,000 cu. yds. earth body was as follows, per cu. yd.:

Labor	$0.219
Plant depreciation	.011
Superintendence	.004
Total	$0.234

The cost of the 6,040 cu. yds. of gravel facing was as follows, per cu. yd.:

Labor	$0.874
Plant depreciation	.022
Superintendence	.020
Total	$0.916

The grand total cost for these two items was as follows:

Labor	$12,976
Plant depreciation	535
Superintendence	270
Total	$13,781

The cost data above given include 30,000 cu. yds. of overhaul amounting to $450, which is not separately considered.

Placing Puddle in a Cofferdam by Pumping. William Martin gives the following in *Engineering and Contracting*, Jan. 6, 1909:

In building Davis Island Dam, several years ago, a cofferdam 1,085 ft. long, containing 5,784 cu. yds. of puddle material, was built by pumping the puddle from an island. The cofferdam consisted of two rows of piles, the rows being 15½ ft. c. to c. and the piles in each row being 21 ft. c. to c. The piles were 20 ft. long, and were driven 8 ft. Three rows of wale pieces or stringers were bolted to the piles, 12 ft. apart. A single line of vertical sheeting plank, driven 2 ft. into the gravel bottom, rested against the wales. The joints of the sheeting were covered with 1 x 6-in. strips to prevent leakage of the puddle. On each side of the sheeting, at the top, was spiked a 2 x 10-in. string piece, to form a bearing upon which a plank deck was laid.

The plant, as finally developed, was as follows: Tubular boiler, 36 ins. diam., x 16 ft. long; engine, 10 x 10 in.; piston pump — steam cyl. 12 x 18 in.; water cyl. 6½ x 18 in.; centrifugal pump, 3-in. discharge; pipes, etc.

The centrifugal pump for pumping the puddle was located on an island 900 ft. from the cofferdam. Beneath the pump was a tank for mixing the puddle, 8 ft. diameter and 4 ft. deep, sunk to a sufficient depth to secure a fall of water from a flume that tapped the river.

The piston pump was connected to the delivery pipe by a wye connection, and was used for priming the centrifugal pump, and keeping the sand from packing, and for furnishing water for the steam boiler and for the agitator hose, as hereafter described.

The puddle, consisting of loam and sand, was obtained within a radius of 100 ft. from the pump by loosening with a plow and delivering close to the tank with drag scrapers. It was then shoveled by hand into the tank, a cost that could have been avoided had the scrapers dumped through a trap into the tank. The material was mixed with water in the tank and kept agitated by water from a hose in the hands of workmen, to prevent the earth from settling to the bottom. This puddle was taken by the feed pipe of the centrifugal pump and forced through the delivery pipe to the cofferdam, a distance constantly increasing as the work progressed. The delivery pipe was laid on the bottom of the river, and then rose by an easy ascent to about 1 ft. above the top of the cofferdam.

The puddle occasionally became so thick as to clog the delivery pipe. In order to meet this difficulty, the following ingenious plan was devised. On the delivery pipe at the centrifugal pump was placed a pressure gage. Any clogging of the delivery pipe im-

mediately caused the pressure to rise, whereupon the engineman slackened the speed of the centrifugal and opened the valve in the wye connection to the piston pump. This admitted a stream of clear water at high pressure from the piston pump and immediately cleared the congestion of puddle in the delivery pipe. The check valve in the delivery pipe between the wye connection and the centrifugal pump prevented a back flow into the centrifugal pump.

One of the principal difficulties in working the centrifugal pump was the rapid wear of all its parts that came in contact with the sand. The casing, which was originally ⅜ in. thick, wore through in 10 days, during which time not 2,500 cu. yds. of puddle were handled. This was replaced with a 1-in. casing which was still in service after the 13 days' use which completed the job.

The stuffing box wore rapidly until the following ingenious device was applied: A screw was cut in the chamber in the opposite direction to the motion of the shaft. A pipe was put in back of the packing and connected with the piston pump. Water was forced through this around the shaft, and, being under a greater pressure than the centrifugal pump, prevented the puddle material from getting into the stuffing box. Water thus applied performed a double duty, for it acted as a lubrication and prevented the shaft from heating.

At the discharge end of the delivery pipe the puddle material was deposited in the cofferdam and flowed off for a distance of a few hundred feet, depositing in a hard and solid mass. The loam being lighter, remained longer in suspension and settled out on top of the sand.

In 23 days there were delivered 5,784 cu. yds. of puddle material, or 251 cu. yds. per 10-hr. day. Laborers received $1.75 to $2 a day, and mechanics $2.50 to $2.75. The cost was as follows per cu. yd.:

Pump ($145)	3.0
Repairs, fittings, etc. ($382)	6.0
Pipe ($364	6.0
Total plant	15.0
Labor	49.0
Fuel	1.0
Total, cts. per cu. yd.	65.0

For comparative purposes it is well to add the following costs of filling another section of another cofferdam near by by another method. The other section was 1,165 ft. long, and it cost $5.69 per lin. ft. for puddle in place, or practically $1.10 per cu. yd. of puddle. The method employed consisted in loading the material by hand into cars, hauling it over a narrow gage track to

the river, loading into boats and transporting to the cofferdam, shoveling by hand into place, and compacting with water. Wages were only $1.25 a day for laborers, and $2.25 for mechanics.

Embankment for the Yale Bowl. *Engineering and Contracting*, July 19, 1916, gives the following:

The construction of the great amphitheater for athletic games at Yale University involved 300,000 cu. yds. of excavation and 175,000 cu. yds. of embankment. The bowl, therefore, differs from most modern amphitheaters in being essentially an earthwork structure. It is built in a level plain by excavating the center of the field and using the excavated material to make an embankment around the outside, this embankment forming a complete oval about the playing field. The seat slabs are placed directly upon the earth, making it a structure which cannot fall down. The surface of the playing field is about 27 ft. below the original surface of the ground, while the top of the embankment is about 27 ft. above the original surface of the ground, the promenade around the top being 54 ft. above the playing field.

A wall 4 ft. high surrounds the field. Access to the bowl for spectators is provided by 30 tunnels, each 7 ft. wide by 8 ft. high. These extend from the ground level outside to about midway of the seat bank, and aisles lead up and down the slope from the inner ends of the tunnels. Access to the playing field from the outside is given by two tunnels, one 15 ft. wide by 10 ft. high and suited for entrance of vehicles, steam roller, etc., and the other 10 ft. wide by 8 ft. high, and suited only for pedestrians, as it contains stairs, being the only tunnel so constructed. Access may also be had to the playing field by a flight of steps at the foot of each aisle. The outside dimensions of the main structure are 933 ft. by 744 and the structure with its approaches covers an area of 25 acres.

The loam which covered the site was first taken off and placed in separate piles of black loam and yellow loam. The depth of the black loam averaged about 10 in. and of the yellow loam about 12 in. Both were of a sandy quality, particularly the yellow loam, some of the latter being but little better than the sandy gravel beneath it.

Dragline Excavator. The gravel was placed in the embankment at first partly by drag and wheel scrapers, but the main dependence for the excavation was placed upon two large dragline excavators operated from 85-ft. towers which moved on elliptical tracks built closely around the outside of the bowl. These towers operated buckets weighing about 4,500 lbs. and having a capacity of about 2 cu. yds. The buckets were hauled in toward the tower by a single cable attached to a drum of the engine and run out by gravity on the main cable, which was pulled up taut

by block and fall attached to the head of the tower, and held taut until the bucket had run out as far as desired and then slackened. The other end of the main cable was attached to a post which was moved from time to time so that the bucket might dig from the exact spot desired. Theoretically, a post could have been located at the center of any section of the track which was approximately a circular arc, and all of the material within the sector could have been removed by the bucket, but several practical considerations prevented this from being carried out in the main part of the excavation, although toward the end, when the banks were trimmed by dragging special buckets up the interior slope, this came very near to being the actual layout.

The maximum output of one of the excavators was about 1,500 cu. yds. running 22 hours, while the largest month's work for the two was about 45,000 cu. yds. Considerable experimenting was necessary before the exact design of bucket was found which would load itself in the bottom of the hole, and would travel up the slope without digging into the bank which had already been built. The proper shape was finally found, and the buckets worked very well with only an occasional accidental digging below grade, which usually took place during the night, when the light and supervision were not particularly good. Quite a little difficulty was experienced in digging through the 10 ft. of sandy gravel, which was fairly compact, although the buckets were heavy and equipped with strong teeth. After this was past, however, the digging was very good and the machines worked easily. Most of the excavation outside of the bowl as well as a portion of that inside was made by two Thew rotary steam shovels with ⅝-cu. yd. buckets loading dump wagons.

Embankment. The specifications called for the embankment above the tops of the tunnels to be rolled in 6-in. layers, and the method of operation was for the drag buckets to make three piles of material between each pair of tunnels, the piles being tent-shaped and usually about 3 ft. high, 8 ft. wide and as long as the bank width. These piles were figured to contain just enough material to make the 6-in. layer, being the most practical way in which to regulate this depth.

As the towers moved along, they were followed up by teams with leveling boards, which leveled off the piles to a fairly uniform surface, and this was thoroughly wet down by water from lines of hose and holled eight times, each point being gone over four times by a grooved roller and four times by a smooth roller alternately. The rollers weighed about 800 lb. per lineal foot and as a rule required four horses, although occasionally a very heavy team would be found which could operate one for a few days without assistance. One larger roller, which required six

horses, was used for a time. Large quantities of water were used. The contract called for 150 gal. per minute, to be run on to the bank night and day.

Below the tops of the tunnels, where rolling was not practicable, the material was watered very heavily, and after the fill had got above the tops of the tunnels, special efforts were made to make sure that the water hed penetrated to every portion of the embankment by damming off a section at a time and running all of the water into this section, and punching holes in the bank about 8 ft. on centers by means of drills of water jets. In this way the whole embankment received a uniform treatment, which could not have been assured otherwise, for the sand was so porous that the water from a 2-in. hose would disappear into the bank within 5 or 6 ft. from the end of the hose, and with operation by the ordinary water boy, it was impossible to tell whether every portion of the embankment had been thoroughly soaked or not.

When the embankment had been carried nearly to its full height, the excess material on the interior slope was dragged up to the top of the bank by heavy timber frames operated by the drag scraper towers in the same manner as a bucket, these frames being about 10 ft. square and heaving heavy iron plates projecting below the front edge, acting much like a leveling board. They could be made to trim just where it was desired by tightening up the main cable so that they could not go below grade at any point, and they did very good work in shaping up the bank. The final trimming was by hand.

The outer slope of the embankment was trimmed partly by leveling boards operated by power and partly by hand, and was then covered with about 10 ins. of loam, into which strips of turf about 8 ft. on centers were embedded, running parallel to the top of the bank, with the idea that they would help to distribute rain water and prevent it from getting together in sufficient volume to do much damage before it struck another line of turf and was spread out again.

The outer slope of the embankment is sloped approximately 1 on 2, except around the portals, where it is about 1 on 1½. These steep places were turfed entirely, but the remainder of the slope was seeded with a mixture of 11½ lb. of red top, 5 lb. of Kentucky blue grass and 20 lb. of white clover. This grew rapidly and seemed to be very good mixture for the purpose, the clover springing up quickly and protecting the grass while it was startling. In this region clover generally dies out after two or three years, while the red top is the native grass and will get a good start by that time.

During the placing of the loam and turf a torential rainstorm occurred, in which the theory of the strips of turf was thor-

oughly tested and found to be correct. Small guilles formed between the strips of turf, being at most an inch deep at the upper end and 3 ins. deep at the lower end and close together, almost as if a very coarse rake had been dragged down the slope from one strip to another. In no instance did the water dip underneath the turf, and the gullies at the foot of the bank were very little larger than those up near the top. The total amount of dirt washed away was small, and the only repair necessary was going over with a rake to smooth the slope up once more.

Design of Hydraulic-Fill Dams. The conditions of solidity and imperviousness required of an earth dam can be obtained with the hydraulic process as readily as with the ordinary method of placing earth by teams or cars in layers and rolling and tamping. With a breast of great height the hydraulic filled dam can be built easier and frequently cheaper if the proper methods are used. Method and cost of hydraulicking are fully covered in Chapter XVIII.

The theory upon which dydraulic-fill dams are generally planned is about as follows: That the inner third of the dam should be composed of impervious material, or material which, by drainage and natural settlement, should consolidate into a mass which will become impervious to water, and remain in a moist, semi-plastic condition; that the outer half of each of the other thirds should be coarse, porous, open material, through which water drainage from the interior, will pass freely; while the inner halves of the outer zones should be a mixture of the coarse and fine, or a semi-porous material, in condition to act as a filter so as to prevent the escape of any of the fine particles from the inner third, but at the same time allow the slow percolation of water through it.

Such a variation in sizes of materials is not always obtainable. Then the engineer must modify his design to meet the conditions.

Predicaments of this sort have led to the invention of the hydraulic-fill, rock-fill dam. In this kind of dam the down-stream side of the breast is built of rock, and the rest of it is hydraulic-fill. The core wall is generally the dividing line, but not necessarily so. Sheets piles are driven along the up-stream end of the rock-fill, to prevent the fine particles of earth from escaping from the center of the dam and flowing away through the rock-fill.

In depositing the sluiced material in the dam, care is taken that the earth is deposited on the slopes of the breast, thus keeping them higher than the center, which allows the water to collect in a pond at that point. This serves several purposes. The weight of water compacts the material as well as permitting the suspended particles to settle to the bottom, thus preventing the wasting of any of the earth excavated. Then, too, the coarse

material is deposited on the slopes, while the finer granules are carried into the center, thus making up the plastic core that is so essential. In rock-filled dams it is evident that it is necessary to place a flume or pipe on the up-stream slope only, as the lower slope is taken care of by the rock.

The excess of water is carried from the pond in the center by flumes, or by syphons, or by connecting the waste culvert in the bottom of the breast by a small shaft, which is built up in successive layers, through the dam, keeping it at such a height as to retain four or five feet of water in the pond. As this water is run off, it can be stored, if necessary, for use a second time. In designing these outlets for the water, when they run through the dam, it must be remembered that the wet material has considerable crushing pressure, and ample strength must be given to the culverts. In a number of cases of dam construction these outlets have failed.

Cost of Hydraulicking the Lake Francis Dam. This involved rebuilding and enlarging an old dam made with teams, part of the breast of the dam having been washed away. This work is described by James D. Schuyler in *Transactions, American Society of Civil Engineers*, Vol. LVIII.

Throughout the reconstruction work the minimum cost for labor on any one week's work averaged 3.8 cts. per cu. yd., sluiced and deposited in the dam. The average labor cost was about 15 cts. per cu. yd., and the total cost was less than 20 cts. per cu. yd., including all power, materials and plant. In all 18,300 cu. yds. were deposited in the dam. The record of power used in pumping showed that it cost 1 ct. per cu. yd. for power. Electricity was used. From the channel below the spillway 9,150 cu. yds. were excavated with the monitor at a cost of 3⅛ cts. per cu. yd.

Hydraulicking the Conculy Dam, Washington. An abstract of a paper by D. C. Henry, Trans. Am. Soc. C. E., vol. LXXIV, is given in *Engineering and Contracting*, May 10, 1911, as follows:

The Conculy Dam is part of the Okanogan project of the U. S. Reclamation Service. The principal dimensions of the dam are:

Greatest height above bottom creek channel, ft.......	66
Width of valley on center line of dam, ft............	815
Length of crest of dam, ft...........................	1,010
Top width, ft..	20
Length of spillway, ft...............................	180
Up-stream slope: upper portion 2½:1, lower portion	3:1
Down-stream slope	2:1
Volume of dam, cu. yds...............................	351,500

Materials Available. The following materials were available for dam construction: (1) Fine sandy loam near the surface, in

the valley bottom, principally to be found up stream from the dam; (2) gravel and sand from the gravel bar to the east of the reservoir, at a distance of from 2,000 to 5,000 ft.; (3) talus material on the west mountain side, just below the dam, consisting of sand and silt from the disintegration of the granite rock, mixed with angular rock fragments of sizes from a man's fist to a cubic yard.

The latter material was selected as that most suitable for the dam, in connection with the method of construction to be followed.

It was considered desirable to place the core section as near forward in the dam as practicable so as to have it backed by the maximum quantity of more open material. As a result, the central plane through the core has a downstream inclination. It was expected that no difficulty would result from this position of the core, as it would be possible to keep the down-stream dumps at a higher elevation than those up stream and thus maintain the central pond at a point well forward toward the reservoir side.

The core section connects with the side-hill by cleaning to bedrock and excavating a rock trench in line with the inclined central core plain. A drainage trench was provided at the downstream toe of the dam, filled with coarse material, hydraulicked in, connecting with the old creek channel below the dam.

Construction. Construction was commenced in the summer of 1907, during which year the following work was done: (1) Building 3 miles of feed-water flume, mostly on steep mountain sides; (2) building a dirt flume, partly on mountain side, partly on trestle; (3) driving and jetting 855 ft. of 6 by 12-in. triple lap, tongued and grooved, sheet-piling, 36 ft. long, for a distance of 33 ft. into valley bottom; (4) excavating 395 ft. of 8 by 9-ft. outlet tunnel, partly lined, through the east mountain side, and excavating a vertical shaft; (5) partial excavation of the spillway gap in the ridge at the west end of the dam.

During the season of 1908, 97,000 cu. yds. of material were sluiced from the borrowpits, and the spillway excavation was completed and lined with concrete. At the end of the season, second-stage flume trestles were erected. During the season of 1909, 188,000 cu. yds. of material were sluiced from the borrowpits, and the permanent gates were installed in the outlet tunnel. During the season of 1910, the remaining 64,000 cu. yds. of material were sluiced, mostly from the second-stage, and partly from the third-stage flumes. The dam was completed during August, 1910.

The original supply flume had a capacity of 17 sec-ft. At the end of the 1908 season it was decided to increase this capacity

to 26 sec-ft. Small storage reservoirs were built above the flume intakes to permit of concentration of the flow during the dry season for two shifts or one shift each day. The large boulders found in the pit had to be broken by blasting, or wasted, to prevent them from accumulating in the bottom. For this reason two pits were kept in operation alternately.

The feed-water was led down the mountain side through 14-in. No. 16 steel, slip-joint pipes, one line of pipe for each borrow-pit, and was used partly by the giant, which consumed from 1½ to 5½ sec.-ft., through nozzles changed from 2 to 3½ ins. in diameter, as required. The water was supplied under a head of 129 to 169 ft. for the first stage, and from 114 to 140 ft. for the second and third stages. A flow of from 2 to 3 sec.-ft. was delivered under pressure through a 4-in. pipe at the head of the borrowpit dirt flume near its bottom, serving as push-water. The remainder of the available water was used as push-water at the point where the pit flume dropped its load into the main dirt flume. A small quantity of water, however, was allowed to enter the pit at its upper end on a level with the supply flume, in order to cause the fine upper material to slide in from above.

A 7x13-in. screen was used at the head of the pit flume during the 1908 season, to exclude large rock, but its use was discontinued after the water supply was increased.

The main dirt flume ran along the lower edge of the pits opposite the point on the dam equidistant from its ends, and then proceeded on a high trestle from the mountain side to the dam. On reaching the dam, the main flume connected on each side with two lateral flumes near the down-stream toe of the dam, and continued to similar flumes close to the up-stream toe. When the dam was built up to the elevation of the first lateral flumes the main trestle was raised 29 ft., and was connected with a new flume laid along the mountain side, while the new lateral flume trestles were built closer to the center line of the dam. In the final finishing of the dam, a single flume was built on trestle near the center line.

The main dirt flume was built with wooden sides slightly inclined outward, and with a curved bottom of No. 10 mild steel with a 12-in. radius. The width at the top was 2 ft. 9 ins. and the total depth 2 ft. 3 ins. The velocity of the water ranged from 14 to 18 ft. per sec.

It soon became apparent that the angular rocks sliding on the bottom caused serious wear, and when 11,000 cu. yds. had been delivered, many holes had been worn within a strip in the center 6 ins. wide, the steel higher up showing little wear. The flume was then given a flat wooden bottom 16 ins. wide, and lined with No. 10 mild steel, which stood the wear far better.

At the end of the first season, when it was decided to increase the water supply from 15 to 26 sec.-ft., the dirt flume was rebuilt to rectangular shape, with a bottom 30 ins. wide and lined with ¼-in. high-carbon steel, and 27-in. sides lined for the lower 6 ins. with No. 10 mild steel. The heavier and harder steel answered the purpose satisfactorily, and lasted through the delivery of 252,000 cu. yds. of material, showing serious wear only at the butt joints.

The flumes had 4% grades, except the short borrowpit flumes, which had 8% grades, and the third-stage flumes for the finishing of the dam, which for part of the distance back had a 3% grade.

The material was discharged from delivery points at the dam in two rows of cones, forming ridges, the principal ridge being along the down-stream slope. By deflecting screens, gratings, spouts, and other means, the coarsest material was discharged, as far as possible outward, and the finer material inward, toward the pond maintained between the two ridges. The surplus water from the pond was drawn off on the reservoir side through flumes near the ends of the dam, which were alternately raised 6 ins. at a time, the pond being maintained at a depth of from 12 to 18 ins.

The material settling in the pond consisted of very fine sand and silt, the coarser sand and gravel coming to rest on the sloping sides of the pond, and the large rock dropping vertically and sliding down the cone slopes. The pond at first was quite wide, but, as elevation was gained, it narrowed up to such an extent that in spite of skillful handling, the sloping coarse sand layers would at times extend well into the puddle section and sometimes clear across it. Such layers were broken up by systematic stirring with paddles, but when this tendency to stratification became more marked and could not be satisfactorily prevented or counteracted, it was decided to introduce an artificial core with puddling material from other sources. The surface material in the valley below the dam, consisting of black, loamy sand, was well suited to form a core. This material was hauled in by scrapers on an up-hill road, dumped on a platform and washed into the dam through an 8-in. pipe. In order to insure against stratification across this core, two wooden diaphragms were built of 2 by 4-in. studding and 1-in. boards, which were first given a vertical position and made to step back in sections, so as to have their center plane correspond, as nearly as possible, with the center plane of the general core, but which were later built in a sloping position. Thus, while the material from the upper borrowpits was hydraulicked in on the slopes, the core material was washed in through the 8-in. pipe between diaphragms. The artificial core was started at an elevation 14 ft. above the general

base of the dam in the late spring of 1909, and was continued about 39 ft. up to the high-water line. It contains in the aggregate 11,600 cu. yds. and, owing to the long haul of about 1,000 ft. on a 7% up-grade, and also to the necessity of using a large quantity of lumber for diaphragms, its cost was quite high.

The coarse rock, as dumped on the outer slopes, was of sufficient size to serve as rip-rap, but it did not prove possible to deposit it to final slopes by the use of water alone, and after hydraulicking was completed, it required a large amount of handwork to obtain reasonably good slopes.

As the quantity of rock found in the borrowpits was larger than had been estimated, the relative quantity of rock on the water slope became sufficient to justify the steepening of this slope from 3 to 1, as had been originally designed, to 2½ to 1

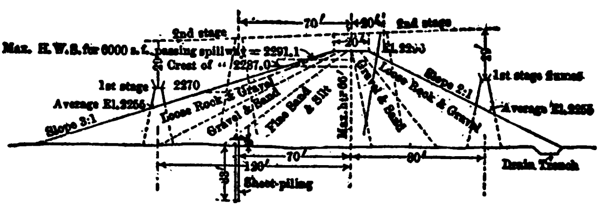


Fig. 23. Cross Section Concully Dam.

for the upper 26 ft. of the dam, as shown by the dotted lines in the central section on Fig. 23.

The dam was built with a super-elevation of 1 ft. across the valley, equivalent to nearly 2% of its height. In view of the hard pounding and washing which the material received in being dumped, and the prevalence of sand and gravel, this provision may seem excessive. During the progress of construction, however, it was found that as the load came on the base, considerable settlement occurred in the trestles, due apparently to a compacting of the fine loamy sand in the foundation. The maximum settlement, extending over the last 560 days of construction being 3.9 ft. along the old creek bed. In total volume, this settlement amounted to 15,500 cu. yds. and while it may have ceased on the completion of the dam, it was deemed wise to finish to the super-elevation above mentioned. Careful watch was kept for possible evidence of a swelling up of the ground surface beyond the toes of the dam, but none was observed.

The swell in volume during the first season was estimated at 12%, but, for the completed work, a lower percentage is computed, as follows:

Sluiced from side-hill borrow-pits, cu. yds.	349,455
Loss in waste water, cu. yds.	20,000
Remaining in dam, pit measurement, cu. yds.	329,455
Volume of dam, cu. yds.	339,900
Swell, 3.2%	10,445

The cost of the reservoir was as follows:

Clearing reservoir site	$7,652
Main Dam:	
Creek diversion	965
Clearing dam site	936
Trenches	1,862
Sheet-piling	13,982
Hydraulicking, 339,900 cu. yds. at 45.8 cts.	155,637
Puddle core, 11,600 cu. yds. at $1.97	22,885
Sloping	8,465
Miscellaneous	1,382
Total for main dam	$208,219
Outlet works	23,114
Spillway	34,613
Telephone	2,827
Real estate	30,977
General investigation of dam sites	19,028
Total cost of 13,000 acre-ft. at $24.95	$324,325

The items in the table include all charges for administration, engineering and general expenses. The cost of puddle core includes lumber for diaphragms. The total material in the dam is 351,500 cu. yds., and the combined cost of hydraulicking and puddle core is $178,522, making the average cost, on the basis of bank measurement, 50.8 cts. per cu. yd., including lumber for core and all overhead charges, but exclusive of the cost of sloping.

The details of the cost of hyraulicking are shown in the following table, the prices paid for labor, per 8-hr. day, being:

Common labor	$2.25 @ 2.50
Pitmen	2.75 @ 3.00
Giant men	3.00
Powder men	3.00
Carpenters	4.00 @ 4.50
Foremen	5.00

Plant:	cts. per cu. yd.
Feed supply dams and flumes	5.04
Dirt flumes and trestles, exclusive of flume lining	5.94
Steel lining	4.40
Pipes, giants and hose	1.09
Electric light plant	0.37
Proportionate share of camp buildings	0.33
Superintendence	1.49
Administration, engineering and general expenses	2.29
Total ($71,204)	20.95
Less value of plant on hand	0.62
Total plant	20.33

Supplies:	
Tools	0.63
Rubber boots and clothing	0.80
Powder and explosives	1.41
Proportionate share of camp buildings	0.05
Superintendence	0.23
Administration, engineering and general expenses	0.36
Total supplies	3.48
Labor:	
Foremen	1.25
Building road to pit	0.17
Clearing borrow-pit	0.16
Feed-supply flume tenders	2.14
Giant men	0.70
Pit men	3.89
Clearing pit of rock	2.46
Building lateral flume in pit	0.28
Hauling and laying pipe in pit	0,79
Dirt flume tenders	2.28
Labor, steel lining	1.46
Spreading material and puddling in dam	0.40
Carpenters on dam and flumes	1.15
Blacksmith	0.27
Operating light plant	0.24
Transporting laborers	0.38
Dismantling plant	0.28
Proportionate charge for camp buildings	0.29
Superintendence	1.34
Administration, engineering and general expenses	2.06
Total labor	21.99
Total cost hydraulicking 339,900 cu. yds., cts. per cu. yd.	45.80

Hydraulicking the Bear Creek Dam. This dam is part of the Jordan River development on Vancouver Island. It was completed in May, 1912, and forms a storage reservoir for an hydro electric plant. C. E. Blee describes the construction of the dam in *Engineering and Contracting*, May 21, 1913.

Some of the dimensions are:

Total volume of dam (embankment measurement), cu. yds.	148,390
Length of crest of dam, ft.	1,017
Greatest height above original ground surface, ft.	57
Greatest height above bottom of sheet piling curtain, ft.	127
Top width of dam, ft.	15
Upstream slope of dam	3 to 1
Downstream slope of dam	2½ to 1
Capacity of spillway, cu. ft. per sec	5,000
Distance of spillway entrance below crest of dam, ft.	15
Distance of high water level below crest of dam, ft.	5

Cut-Off Trench. As soon as stripping had advanced far enough to permit it, work was started on a cut-off trench, extending throughout the length of the dam and parallel with the axis, the center line of the trench being directly under the downstream edge of the crest of the dam. This trench (Fig. 25) was 6 ft. wide at the bottom, and averaged about 20 ft. deep, with side slopes of

¼ to 1. At both ends of the dam it was carried down to bedrock as far as the practicable depth of the trench would permit, the bedrock dipping rather rapidly toward the center of the valley. The material excavated consisted of a semi-cemented gravel, and heavy boulders with thin layers of sand at deeper levels. The first lift of 5 or 6 ft. was shoveled directly into wheelbarrows. The greater part of the remainder was removed by a steam derrick with skips, a hand derrick also being used in some extent. The smaller material in the section under the old stream bed, where considerable water was encountered, was removed with a hydraulic elevator.

All material excavated from the trench was placed in the embankment, excepting near the ends where, due to the narrowness of the base of the dam, but little of this material could be used, and it was more economical to waste it than to haul it to the wider portions. In placing material of any description by means other than sluicing, care was observed to keep it well without the limits of the middle third of the section, in order to reserve the central portion for the puddle material deposited under water. The material from the trench excavation placed in the embankment was largely used to start the toe of the slopes of the dam, thus forming dikes some 5 ft. or more in height, which would serve to retain the sluicing pond and to be otherwise useful at the time of starting the fill by sluicing methods.

The total volume of material removed from the trench was 8,675 cu. yds. The direct labor cost of excavation when a steam derrick was used was approximately $1.00 per cu. yd.

Borrowpits. The main borrowpit was located on the north side of the valley, directly opposite the dam and about 400 ft. from the north end of the dam axis. Test pits showed this to be the only available deposit sufficiently large to furnish the material for the embankment. The material was a hard-pan made up of sand, gravel, and boulders, mixed with clay, and overlying the bedrock in depths of from 8 to 18 ft. It was not an economical material to handle, as it was necessary to break it with powder; it required a heavy grade on the flumes, and a large amount of boulders had to be handled and wasted in the pit; but it was so proportioned that when segregated and deposited by the hydraulic process it formed an embankment which, for stability and imperviousness, could not be surpassed.

Small borrow-pits were opened on the south side of the valley to be used in finishing the south end of the dam. The main pit was at an elevation of from 150 to 250 ft. above the valley floor, which is equivalent to 95 and 195 ft. above the crest of the dam.

Equipment for Sluicing. A gravity supply of water was ob-

tained from a small tributary creek rising on the north slope of the valley, and entering Bear Creek just below the dam. A crib dam, 13 ft. in height, was built near the head waters of this creek, forming a storage reservoir with a capacity of approximately 1,500,000 cu. ft., which was sufficient to operate the sluicing five to seven days, aided by the natural flow of the creek. This storage proved very useful, as the stream fluctuated rapidly with weather conditions, running very low in dry periods or in freezing weather. The water was diverted at a point about half a mile from the dam site, and carried by means of a 10-in., spiral-wound wood-stave pipe to a head-box above the borrow pit. This pipe had a capacity of approximately 7 cu. ft. per second. From the head-box to the borrow-pit, a distance of about 400 ft., an 8-in. slip-joint riveted steel hydraulic pipe — No. 12 gage — was laid. A gate was provided at the head-box and two 2-in. standpipes installed as air valves. Care was taken to anchor this pipe, especially at all angle joints. A Y-piece was installed just above the borrow-pit, with one pipe leading down the west side, and the other down the east side of the pit. Both were provided with gate valves near the Y. The monitors were connected directly to these pipes, which were shifted about as the progress of the work required. The static head at the nozzles ranged from 125 to 225 ft., giving discharge of from 3 to 6 cu. ft. per sec. Nozzle tips of 3 and 4-in. diameter were used.

Pumping Plant. A pumping plant was installed just below the dam near the creek, to be used whenever the gravity supply ran low, and so avoid, as far as possible, delays in sluicing operations. This was considered necessary as it was imperative that the dam be completed in time to store water for use during the summer of 1912. The plant contained two three-stage centrifugal pumps, 6-in. discharge, 1,000 gals. per minute capacity, the pumps being driven by steam engines, equipped with four 50-hp. boilers. Wood cut near the site was used for fuel. When running at full capacity, about 25 cords were burnt per 24 hrs. This was delivered at the plant at an average total cost of $3.50 per cord.

The small borrowpits south of the dam were operated entirely by water from the pumps.

For lighting the works, 16 c. p., incandescent lamps, were strung on each deck of the main flume and laterals, the power being generated by a D. C. 100-amp. 125-volt dynamo, operated in connection with the pumping plant.

Sluicing Flume. A main flume (Fig. 24) of three decks was erected to carry the sluiced materials from the borrow-pits into the dam. This flume extended the full length of the dam, parallel to the axis, and with its center-line 8 ft. upstream from the up-

stream edge of the crest. It was so located in order to be clear of the cut-off trench, but ordinarily it is better practice to keep the flume within the lines of the crest so that as the fill approaches the crest, any overflow from the flume will not tend to wash out the newly formed slopes.

A flume box was carried on each of the three decks. The paving blocks used in the bottom of the boxes were cut on the site, and it was found economical to select the best fir timber for these. It was necessary to replace these blocks after the passage of about

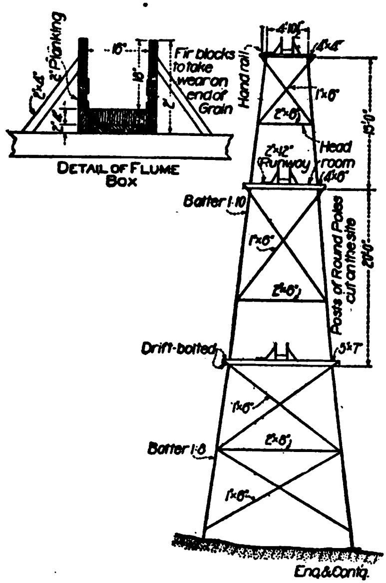


Fig. 24. Main Sluicing Flume Bear Creek Dam.

25,000 cu. yds. of borrowpit material, and even before this they would become so badly hollowed out and worn as to interfere considerably with the flow of the sluiced material. There was but slight wear on the sides of the flumes, the original boards lasting throughout the work. A grade of 6% was used on the main flume, and this proved to be as light a grade as could be used with the dense heavy material which was found in the borrowpits here.

Lateral flumes, branching off from the main flume, and then curving and extending along near the face of the slope and parallel

to the axis, were erected to distribute the material along the edges of the rising embankment. Two types of laterals were used, according to the construction of the flume-box. The longer and more permanent laterals had a box with flush or butt joints and of practically the same construction as the main flume box, also the same grade — 6% — was used on these. The material was dumped by means of gates or openings in the sides of the box, and where necessary for the placing of the material, spouts were attached to these openings. The box on the other type of lateral had telescopic or lap joints, and was of lighter construction throughout. Grades of 7 and 8% were necessary with these, because of the loss of grade due to the lapping. The material was dumped from the telescopic boxes by simply displacing them at the joints where desired. As the slopes approached the crest, the material was distributed directly from the main flume by means of spouts.

Sluicing. Sluicing was started Sept. 1, 1911, and carried on as nearly continuously as possible in day and night shifts of 12 hours each. Delays were encountered due to weather and flood conditions, so that sluicing operations were maintained 67% of the total elapsed time after starting. However, the fill was completed April 15, which was earlier than had been anticipated.

Weather as cold as 5° F. above zero was experienced, and the snow on the ground reached a depth of about 3 ft. The extreme cold interfered with the flow of the sluiced material by the freezing along the edges of the sluiceways and the formation of ice on the sides of the flumes. Also the ice on the sluicing pond attained considerable thickness, but this was overcome by laying steam pipes around the edge of the pond, and introducing live steam from the boiler plant. With the outside temperature ranging from 10° to 25° F., it was necessary to operate the thawing system about 12 hours out of 48 to keep the pond comparatively free of ice.

During the months of November and December some severe delays were occasioned by maintaining the temporary spillway through the dam. Further delays were due to a failure of the gravity supply of water, when suitable borrowpit material was not available at an elevation to be economically reached with pumped water.

In the borrowpit, a nozzle was maintained on each side of the pit, the two being operated alternately in periods of about six hours. While the nozzle was in operation on one side, the crew would remove the boulders from the sluiceways, and put in the blast holes for breaking the ground on the other side. It was necessary to break all the ground with powder. "Gopher" holes were put into the base of the banks to a depth of from 10

to 16 ft.; also in places where the ground was shallow down-holes were put in by driving 1-in. drill steel.

The larger masses resulting from the heavy shots were "bulldozed" and the whole further broken down with picks. Throughout the work the amount of powder used in the complete breaking of the ground ran remarkably close to ¼ lb. of powder per cu. yd. In the "Gopher holes" 25% dynamite was used, and 40% was used for "bulldozing."

A fairly large proportion of the boulders were too large to be transported in the flumes with the amount of water available, and these had to be handled and wasted in the pit. They were removed from the sluiceway when the nozzle was not in operation, and were generally thrown out on the side toward the center of the pit, so as to form a wall or dike which would confine the water in the sluiceway and tend to throw it in toward the bank. This had the effect of cutting out the sloping toe of the bank and keeping the face vertical, which was of considerable help in putting in the "Gopher holes." It is estimated that 10% of the total material removed was handled and wasted in the pit. Also when the sluicing was in operation, men were kept in the sluiceway with long, pronged rakes removing the larger boulders and keeping the material moving. It was found necessary to keep the sluiceways cleaned right down to bedrock, or the material would start to deposit and block up, even where the grade was as steep as 15 to 20%. The stream from the nozzle was frequently turned into the sluiceways to push the material. Later on in the work, flume boxes were carried up closer to the working face, and this did away with much of the work of maintaining the open sluiceways on the bedrock.

A donkey engine was used for pulling and removing stumps as they were undercut by the excavation. It was also used in removing large boulders, and a stone-boat was used to some extent in removing rock.

Flume tenders were stationed on the flume to keep the material moving when blockades started to form. These blockades were fairly frequent, and when they occurred it was necessary to stop sluicing and run in clear water from the nozzle. Two men were kept on the lateral flumes to attend to the depositing of the material along the edge of the embankment.

As the material was deposited from the flumes, the boulders and coarse gravel would form conical piles, while the lighter material was carried off by the water toward the sluicing pond, the material being graded and deposited as the velocity of the water decreased until when it reached the edge of the pond and the velocity was entirely checked, all sand, etc., was immediately dropped, and nothing but the fine clay silt was carried in to

the puddle core. From the edge of the embankment when deposited, the material formed a slope of about 5% until the edge of the pond was reached, when it dropped off abruptly at a slope of 1 to 1. The surface of the puddle forming the bottom of the pond was practically level.

An average crew of eight men was employed in shoveling to slope the piles deposited from the flumes.

No difficulty was experienced in maintaining the slopes, as the outer portion of the embankment was built up entirely of boulders and coarse material which gave stable, well-drained slopes. Boulders as large as 8 ins. in diameter were delivered through the flumes.

By sluicing from different sections of the borrowpit, it was possible to select material with differing proportions of clay and coarse ingredients. This proved quite helpful, especially as the dam neared completion, for if the sides were building up too fast in proportion to the puddle, material could be selected that carried greater proportion of clay.

The puddle core was examined on several occasions when the pond was drawn off, and showed no tendency toward stratification. The first few inches on the surface of the puddle was very light and fluffy, but at a depth of 2 ft. or so it became stiff and fairly solid, showing that it drained and solidified rapidly.

An outlet for the sluicing pond was, in the earlier stages of the work, provided by a timber culvert extending in from the downstream toe of the dam to a vertical shaft, also of timber. This shaft was carried up as the work progressed, the level of the pond being regulated by openings or gates in the shaft. The depth of the pond was usually kept at from 3 to 6 ft., according to the width desired for the puddle core. As soon as the embankment had reached an elevation such that the pond backed up into the north end of the cut-off trench, a deep narrow ditch was cut from this into the spillway, so that the pond would now discharge through this ditch, by way of the cut-off trench. This was desired in order that any current set up in the sluicing pond would tend to carry puddle material up into the north end of the trench, for it was feared that there might be a shortage of puddle for this portion, due to the narrowness of the dam section here. The level of the pond was now regulated by placing sandbags in the entrance to the ditch, and the waste water was discharged into the reservoir by means of a small flume. This was done simply as an extra precaution in order that the fine material carried by the waste water might tend to silt up the reservoir floor.

As the fill neared completion, the puddle core was carried up to high water elevation, and then, in topping off the embankment, mixed material was dumped in directly from the flumes with-

out maintaining any pond. The work of topping off was started at the south end, the water draining off at the north end.

RECORD OF SLUICING OPERATIONS

	Gravity sluicing	*Pumping*
Number of 24-hr. days worked (214)	145	69
Actual sluicing time, hrs	2,347	1,084
Time efficiency, %	66	64
Average water used, sec.-ft	5.6	3.0
Material placed in dam, cu. yds	92,490	32,015
Ratio of material to water, %	5.3	7.3
Cu. yds. per 24 hrs. straight time	640	460
Cu. yds. per 24 hrs. sluicing time	946	709
Cu. yds. per sec.-ft. of water	169	236

Cost. Following is a list of the average force employed in the borrowpit, and on the dam:

BORROW-PIT CREW

Day Shift —	
1 Foreman	$5.75
6 Drillers (breaking ground), 11½ hours at 30 cts	20.70
5 Laborers (rocking out sluiceways), 11½ hours at 30c.	17.25
1 Nozzleman	4.00
Donkey engine crew	16.75
Night Shift —	
1 Nozzleman	$4.50
4 Men (breaking ground and rocking out), 11½ hours at 30 cts	13.80

CREW ON DAM

Day Shift —	
3 Flume tenders on main flume, 11½ hours at 30 cts	$10.35
2 Tenders on lateral flumes, 11½ hours at 30 cts	6.90
8 Laborers building up slope, 10 hours at 27½ cts	22.00
Night Shift —	
3 Flume tenders, 11½ hours at 30 cts	10.35
2 Tenders on laterals, 11½ hours at 30 cts	6.90
1 Foreman	5.75
Total labor cost	$145.00
Powder for breaking, 1,000 cu. yds. = 250 lbs	30.00
	$175.00

From this force account it is seen that when sluicing with gravity water, and placing 1,000 cu. yds. per 24 hrs., the normal capacity when no delays were encountered — the powder and direct labor cost of taking the material from the borrowpit and placing it to slope in the dam was practically 17½ cts. per cu. yd.

The cost for 7 months operation, including, in addition to powder and labor costs given above, all labor and fuel and supplies for pumping plant operation and maintenance, superintendence, and all labor and material for maintenance and extension to pipe lines and flumes, was $54,277, which for 127,035 cu. yd. is 42.5 cts. per cu. yd.

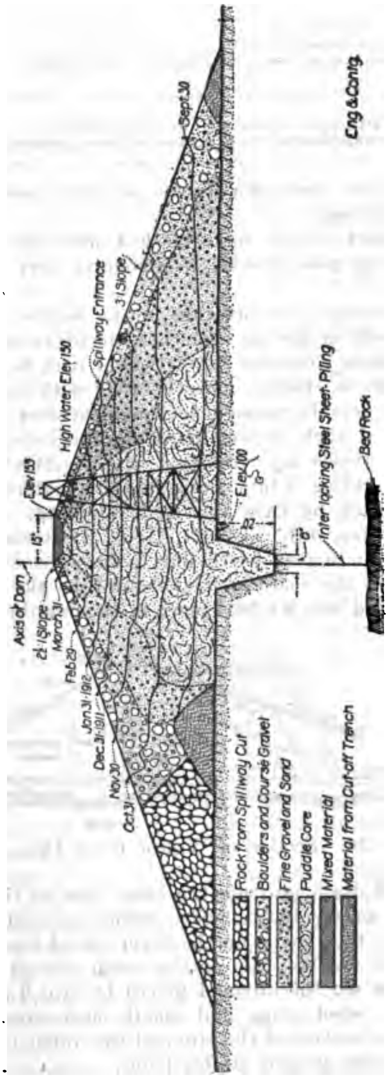


Fig. 25. Section of Bear Creek Dam.

A summary of the material placed in the dam is as follows:

Rock from spillway cut	8,285
Material from cut-off trench	5,700
Sluiced from borrow-pit (measured in excavation)	129,364
Total cu. yds	143,349
Completed structure (measured in embankment)	148,390
Excess of embankment over excavation measurement, 3.6%	5,041

The figure given above for excess or swell would be modified by two conditions.

(1) The amount of fine material lost with the waste water from the sluicing pond would, if accounted for, increase this figure.

(2) In measuring the excavation in the borrow-pit, the piles of waste rock left in the pit were considered as solids. If the voids in these were corrected for, it would tend to decrease the above figures. It is evident, however, that with no losses there should be a considerable excess of embankment over excavation in taking a material such as was found in the borrowpit here — which as far as voids are concerned was practically a natural concrete — and grading it into coarse and fine material.

Dam Construction by Cars and Hydraulicking. In *Engineering and Contracting*, July 19, 1911, H. L. Bickerson describes a method of constructing an earth dam across the Willow River, Oregon, in which the material was hauled to the embankment in cars and washed into its final place in the dam by nozzles.

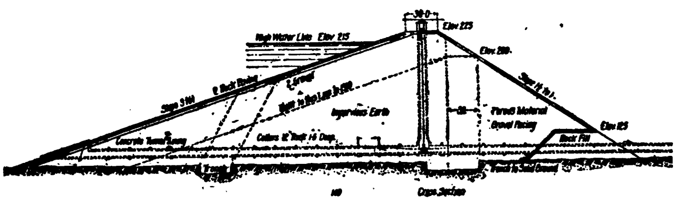


Fig. 26. Section of Willow River Dam.

To secure good drainage from the lower side of the structure, rock fill, approximately 100 ft. wide on the base and 25 ft. high, was placed across the canyon on the lower toe of the dam. Rock was secured from the lava cap on the north side of the canyon, which was shot down the hill and placed by two 9 x 14-guy derricks with 1-yd. steel skips and small push cars. The rock stripped from the surface of the site and excavated from the cut-off trenches was also wasted at this point.

A dry earth dyke was extended across the canyon on top

of the rock fill. The material was delivered in trains of five 5½-yd. cars with a dinkey engine. The end car of the train was made to dump endwise, thus extending the dike in that direction, while the other four cars were dumped toward the center of the dam, the material from the side dump cars being washed toward the center of the dam, the material from the side dump cars being washed toward the upper toe, where a low dry dike was maintained, with water forced through a 1¼-in. nozzle under pressure produced by a 750-gal. Knowles Underwriters pump. The lower dike was kept enough higher than the upper one so that the puddle containing the finer and impervious material was always nearer the upstream face of the dam, and the coarser material in the lower half of the structure, any excess water being drained out through and over this low upper dike. The sluiced material was usually solid, and it was possible to walk on any part of the puddle shortly after water was turned off. Tests made during construction showed that the weight of the material in the pits averaged 104 lbs. per cu. ft., and in the dam, thoroughly saturated, 123 lbs. The quantities as measured in the dam checked the quantities computed from cross-section of the material pits within 2½%.

Trains placing the earth fill consisted of five and six cars, the end car being a rebuilt car to dump endwise, thus extending the dike across the canyon while placing material into the dam. The dump crews consisted of five men, three on the dump shoveling and clearing track, and two working the nozzle in the sluicing operation. Train crews consisted of engineer and brakeman; shovel crew consisted of engineer, craneman, fireman, and four pitmen.

The operations were carried on with one Model 40 Marion shovel with 1½-yd. dipper, two 14-ton Vulcan locomotives, and sixteen 5½-yd. Peteler two-way dump cars, all standard gage. The material was sluiced into place by a 750-gal. Knowles Underwriters pump, served by a 60-hp. Kewanee boiler, and the rock fill was placed with two 9 x 14 American Hoist & Derrick Co.'s guy derricks.

Placing earth from the borrow pits was commenced on Aug. 12, 1910, and on Jan. 22, 1911, the dam was completed to the 100-ft. elevation, 286,000 cu. yds. having been placed. The work was carried on in two 10-hr. shifts, laying off one shift per week for general overhauling and repairs to plant. The best monthly run was in September, 1910, when 63,570 cu. yds. were placed in 55 shifts, or an average of 1,156 cu. yds. per shift.

The average haul from pits to dam was 2,500 ft. The pits when opened up were 1,200 ft. in length, with an 18-ft. face. For the completion of the structure to 125-ft. elevation, new pits are to be

opened up directly north of the dam and the excavation thus made is to serve as the permanent spillway.

In the preparation of foundations, 19,000 cu. yds. of material were excavated, all by hand, and wasted both outside and inside the slopes of the dam. This material consisted of large boulders, brush and vegetable matter, soil and silt, part of the excavation being wet, and all being transported either by wheelbarrows or small push cars. The cost per cubic yard for this work was $1.28. The cost of 9,000 cu. yds. of rock fill, including cost of drilling and shooting, was $1.41 per cu. yd. This cost also includes transporting to place, 1,117 cu. yds. of concrete in the outlet tunnel and controlling works was $14.82 per cu. yd. The cost of the earth fill was as follows, per cu. yd.:

Excavating and Loading:	
Labor drilling	2.3
Labor shoveling	4.7
Powder	2.7
Fuel	3.3
Total	13.0
Hauling and Placing:	
Labor, track	1.4
Labor, dumping and sluicing	10.6
Fuel, engines and pumps	6.4
Total	18.4
Grand total, cts. per cu. yd.	31.4

This gives a cost per cubic yard for labor of 19 cts., and for material of 12.4 cts. The wages paid were as follows per 10-hr. day:

Common labor	$2.25 to 2.75
Steam shovel enginemen	6.17
Steam shovel cranemen	4.67
Locomotive enginemen	4.00
Carpenters	4.00 to 4.50

The average cost of lumber at the site was $25.00 per M ft. B.M.; cost of cement $4.46 per bbl., and cost of coal $13.50 per ton.

Hydraulicking the Los Angeles Dam. *Engineering Record,* Feb. 3, 1912, gives the following: The South Hawaii dam of the Los Angeles Aqueduct was composed of earth delivered in dump cars and jettied to place by streams of water delivered from nozzles. The dam is designed to contain 559,750 cu. yds. of earth, exclusive of the contents of the cut-off trench. It is 1,523 ft. long and has a height at the center of 91 ft. The width at the top is 20 ft. and the slopes are 2½ to 1 on each side.

The bed rock is overlain with a decomposed tufa shale. Test pits 75 or 80 ft. deep were dug and the soil stood up without timbering. A trench was then excavated by steam shovel to a depth

of 14 ft. along the axis of the dam. This was filled with water and within a week the ground settled 12 ins. for distances as great as 75 ft. each side of the trench. This proved that it was necessary to take the cut-off trench to bed rock, which was reached at a depth of 120 ft. Ground water was encountered at a depth of 75 ft. The material was mainly shale soils with a 3-ft. stratum of sand and gravel at the bottom.

This trench was excavated with light, stiff-leg derricks, and dump buckets. The spoil in the dumps was hauled to the lower toe of the dam with scrapers. The trench was timbered throughout. The impervious core was composed of clay, which was excavated by an electric shovel and hauled an average of 1,000 ft. in dump wagons to the side of the trench, into which it was pushed by a road grader. The trench was kept filled with water, and the force of the fall thoroughly compacted the clay. The cost of the cut-off trench (27,032 cu. yds.) was as follows:

Labor	$22,422
Live stock	2,280
Materials and supplies	1,843
Electric power	957
Freight	630
Total excavating cost	$28,132
Cost per cu. yd.	$1.04
Timbering:	
Labor	$15,144
Live stock	457
Other charges	25,790
Total for timbering	$41,391
Cost of timbering per cu. yd.	$1.53
Cost of puddle fill per cu. yd.	0.315
Grand total cost per cu. yd.	$2.885

The material for the body of the dam was excavated from a pit 1,000 ft. from the dam with a 60-ton Marion steam shovel. The soil was loaded into 4-yd. double-side dump cars, and hauled in three trains of 7 cars each by three 18-ton Vulcan locomotives, running on a 3-ft. gage track. While one train was being loaded, another was in transit and the third was being dumped. The grades were 3% up-grade for loaded trains and 6% down-grade for empties. The shovel had a 2.5 yd. dipper; two dippers filled each car. When conditions were favorable it required 4 mins. to load a train. From 400 to 500 cars were loaded in two shifts. The day shift accomplished about 50% more than the night shift. The best day's run up to Oct. 31, 1911, when 184,000 cu. yds. had been placed, was 700 cars or 2,100 cu. yds.

The hauling track divided when it reaches the dam, a branch running up along each toe. Thus two walls were built up.

The waters of two streams were discharged in the space between these walls, and in the pool thereby formed two steel pontoons were floated. These pontoons were 20 x 10 x 2.5 ft. in size. Each carried a 6-in. centrifugal pump direct connected to a 30-hp. electric motor. Power was supplied through an insulated cable thus allowing changes in the location of the pontoons. The water was discharged through a 2-in. nozzle against the banks of earth dumped from the trains. The earth was washed down towards the center of the pool, the coarser material remaining at the edges of the pool and the finer stuff going to the center. This center material was very fine and clayey. The use of two tracks permitted one to be shifted and raised while the other was in use. The cost of the first 184,000 cu. yds., including 50,000 cu. yds. placed by wagon work, was 22 cts. per cu. yd. The cost of the work complete was estimated to be about 15 cts. per cu. yd.

Hydraulicking the Abott Brook Dike. *Engineering and Contracting*, Feb. 26, 1913, contains an article descriptive of the plans and methods used in constructing the Abott Brook Dike, an earth dam located on the westerly side of Sawyer Lake, near the headwaters of the Androscoggin River. This dike is 900 ft. long, 165 ft. wide at the base, and about 16 ft. wide at the top, and has a 6-in. plank core composed of two layers of 3-in. plank. The total volume of the dike is 46,000 cu. yds., of which amount 1,600 cu. yds. were placed by manual labor to form the toe of the dike, and for the puddle fill at each side of the core in the cut-off trench. About 31,165 cu. yds. were pdaced by hydraulic sluicing methods.

The plant used comprised two 150-hp. turbine driven pumps, direct connected to 3-stage, 8-in. centrifugal pumps, designed to run at speeds ranging from 1,800 to 2,000 r.p.m. The main pressure line of pumps to borrowpit was 600 ft. long and 10 ins. in diameter. Branches connecting this main with a 2-in. giant were 350 ft. long and 7 ins. in diameter. Steam to run the turbines was furnished by a battery of 8 boilers, consisting of two 50-hp., three 40-hp., and three 30-hp., and a feed water heater. Steam pressures at the boiler ran from 80 to 150 lbs., and the pump pressure was from 45 lbs. per sq. in. down to 20 lbs. per sq. in., depending upon the elevation, with an average of about 45 lbs. per sq. in., with a 2-in. monitor discharge stream.

Two water jets, with a pressure of from 20 to 80 lbs. per sq. in., were directed against the bank in a borrow pit at the northerly end of the dike. The force of the water was so great that although the nozzles were securely mounted on swivel bases, a long lever had to be attached to each nozzle to enable one man to control it; under certain conditions, two men were required.

The flumes were rectangular wooden structures, supported on wooden trestles, built with even slopes from the borrow pit to the dike. The main flume was about 1,000 ft. long, and the main trestle about 40 ft. high at the tallest point. The laterals discharged at the edges of the fill, and in this way the loose stones and coarse material remained at the edge, and the finer and silt were carried toward the center.

The dam was situated far from the railroad, and it was difficult to get a sufficient supply of coal. The little that could be obtained cost $20 per ton, and it became necessary to use wood for fuel. A total of 1,860 cords of wood were burned. Counting the 55 long tons of soft coal used as equivalent to 2 cords each of wood, the equivalent of 1,970 cords of wood were burned.

The material was a glacial drift of sand, gravel, clay, and small stones so firmly compacted that it was found advisable to resort at times to dynamite. Holes about 8 ft. deep and 8 ft. apart were drilled, and about 6 lbs. of 16% dynamite used per hole, and set off in batteries of from three to seven holes.

Sluicing was carried on for 32 (10-hr.) days and for 68 (24-hr.) days; equivalent to 82 full days. The men worked on two shifts of 12 hours each, working week days and Sundays continuously, the only stop being for unavoidable delays in cleaning and repairing. The average yardage placed per day was 380 cu. yds.; the best weekly record was 3,891 cu. yds., an average of 556 cu. yds. per day. These measurements were determined by weekly cross sections of the embankment. The volume of solids moved in the water averaged a little better than 6%.

Hydraulicking the Somerset Dam, Vt. *Engineering News*, Dec. 25, 1913, gives the following: This dam is located at what was Peck's Mill in the town of Somerset, Vt. It is 2,100 ft. long on the crest and has a finished height of 106 ft. It contains about one million cu. yds.

A cut was opened with steam shovels to a borrowpit on the west side of the dam. This cut was run for about a half mile on an upgrade of 5% maximum, passing through a number of rock ledges. The location of the pit was a gently rising slope which by test pits had been found to contain a glacial drift with some 30% of clayey material and running from very fine material to sand, gravel and boulders, well graded. The pit was opened up on two levels and, as the height of the dam increased, the shovels worked farther up the hillside, the result being that the downgrade from the pit to the dam was gradually decreased, though not much. At first there were seven dinkey locomotives (19-ton) and 70 4-yd. narrow gage cars. For the last season's work, however, three more locomotives were put on and 30 more

cars, making in all 10 locomotives and 100 cars. During the last season too, a borrowpit was opened up on the east side of the dam and a third 2½-yd. steam shovel put in, reducing the length of haul for a considerable part of the fill.

First, in starting the fill, a couple of 20 to 30-ft. trestles were run out some 50 ft. inside the upstream and downstream toe lines of the dam, and material from the pit was dumped off these, working out from both ends of the dam. These four toe fills were thus pushed out until the water was reached when the gap in the upper dike was filled in. When this was done, the water rose until the entire flow was through the conduit. The pool between the two dikes could then be drained through the gap in the lower dike and the remaining work of stripping the site completed.

When the work was in this stage, a pumping plant was built just above the dam, taking water from the reservoir for 6-in. supply pipes laid along both trestles. There were in this plant three 60-hp. locomotive boilers, two compound duplex pumps rated at 750 gals. per min. at 200 lb. pressure, and one smaller pump as a spare unit. Only 150 lbs. pressure was held on the pipe lines, however. The lines were fitted every 50 ft. with T fittings and valves for connecting on lengths of 3-in. rubber sluicing hose fitted with 1½-in. taper nozzles mounted on portable wood stands as monitors.

The material dumped from the trestles was undercut with streams from these nozzles and washed down into position. A pool was created between the two dikes and the finer material settled in the center. At times alum was used in the sluicing water to increase the precipitation of clayey material, but this was finally abandoned as unnecessary. An 18-in. concrete pipe was carried up from a hole in the outlet conduit. Through this the excess water was drained and the depth of the pool regulated, being allowed to vary between 10 and 20 ft. The outside faces of the two dikes were filled with coarser material and boulders from the pits, and this, on being washed down into place, gave satisfactory rock face without riprapping.

When the washed fill reached the level of the trestles, the tracks were shifted inward. Five heights of trestle were run in during the work on the dam. The old timbers were not pulled.

Samples were taken at each 5 ft. along the length of the dam to see if sufficient fine material was being deposited to build up an impervious core. In sounding the center pool the bottom at each stage was always found quite hard, and the examination of the accumulated samples shows that the fine material has considerable binding property. The two years occupied in construction, 1911 to 1913, gave opportunity for set-

tlement which was small, but the dam was carried to an excess height of 4 ft. to provide for future shrinkage.

Accident to, and Reconstruction of the Charmes Dam. *Engineering and Contracting*, May 29, 1918, gives the following:

The Charmes Dam in France was completed in 1906. It is about 1,190 ft. long, 55 ft. high, and 22 ft. wide on top. The up-stream face is built in 5.5-ft. steps, giving a general slope of 1½ to 1. The down-stream slope is flatter and has a slightly concave force.

The dam was constructed in a series of layers of good clay mixed with 5% of fine crushed rock, each layer being puddled and rolled with a corrugated roller. The layers were 5 ins. thick before rolling, which reduced them to 3 or 4 ins., making the earth remarkably hard and compact. Allowance was made so as to make it follow the required slopes, and the layers were put in rapidly to be always on freshly puddled material. The face was paved or covered with concreted slabs 8 ins. thick, with clay joints.

After the dam had been in use three years a longitudinal fissure developed a little above the top bench on the inside slope. The water was being drawn off at the time, and as its height was lowered a slide developed. The amount of the slide was about 26,200 cu. yds. It was decided that the repairs would be made of the same clay compacted by the same process to a proper hardness, and for security it was decided to reinforce the lower part 8 ft. above the cut-off wall, the foundation of it being considered perfectly good. Two other conditions were adopted, first, the physical improvement of the Charmes clay by the addition of a considerable amount of small pebbles; second, the construction of buttresses in the reinforcements.

The necessity of adding pebbles to the clay to be used for the puddled wall 48 ft high on a slope of 1.5 to 1 was determined upon, which plan had been used at the Liez dam, and, probably on account of which it has stood for 25 years; and was used in the Wassy dam repairs. Such a mixture is very much superior to any other for puddled material for dams.

There being no pebbles or gravel in the vicinity, it was necessary to resort to crushed stone which was a valuable material and could not be used wastefully. Experiments were made to determine the proper amount to be used and 20% was finally adopted as best. The earth work for the repairs was done largely by hand, using small horse drawn cars to transport the materials.

The addition of buttresses was considered necessary, and it was decided they need not go all the way up the face of the

dam, as insisted upon by some constructors, but only to be carried up to the height of the danger zone or 29 ft. above the top of the cut-off wall. They were 4 ft. 7 in. thick and averaged 49 ft. in length. They were built of concrete similar to that employed in like work. Where they join the cut-off wall they are enlarged in the form of a girder, thus approaching the form of a solid of equal resistance.

Particular precautions were taken to prevent "water ways" where water would follow the junction of the puddled material and the concrete masonry, so the buttresses were put in at a time and in a manner that they would not interfere with the rolling of the puddled material. The plan for the restoration comprised a complete drainage system from the top to the bottom.

The paving slabs were made by crushing the broken ones from the former work, using an excellent sand to make the concrete. The new top step was an improvement over the old.

The repairs were made from 1909 to 1911 and were quite difficult, as the year 1910 was unfortunately very rainy. The cutting away of the slide and old face was done in the first 6 months and all the work was carried out under considerable difficulty. The total cost of the work was 500,000 francs.

A Slide on the Stanley Lake Dam. John E. Hayes, in *Engineering News-Record*, May 31, 1917, gives the following: This dam was hastily built. At first material was dumped from trestles on the up and down stream toes into a pond of water that was kept between the trestle embankments. At the 30-ft. level it was found that the puddle material was not drying out. Thereafter up to 64 ft. elevation, material was scattered in thin layers with teams and scrapers over the puddle core area, sprinkled by means of hose, and compacted by the team travel. Above the 64-ft. level to the top of dam at 70 ft. elevation the trains were depended upon for consolidation. The dam was completed in 1912. In the summer of 1916 while water was being drawn from the reservoir a large part of the up-stream face of the dam slid into the reservoir. Approximately 88,000 cu. yds. of material was displaced. Owing to the different methods of construction adapted this dam was not a homogeneous structure.

Slide on the Calaveras Dam. *Engineering and Contracting*, July 10, 1918, and Jan. 8, 1919, gives the following:

The Calaveras Dam was being built about 36 miles southeast of San Francisco by hydraulicking. Its top length was to be 1,300 ft. and its top width 25 ft. The upstream slope was 3 to 1; the downstream slope, $3\frac{1}{2}$ to 1; and the maximum

distance between upstream and downstream toes, 1,312 ft. Its finished height at the center was to be 210 ft. above ground level, plus 30 ft. above the bottom of a wide excavation to solid bed rock. About half the material in the dam was a dry rock fill used in both toes; the rest was an earth fill deposited by hydraulic sluicing. The earth fill was half clay and half sand and gravel hydraulicked from nearby hills. The coarse material was crushed before entering the conveyance pipes. The hydraulicked material was dumped on the edge of the pool, thus permitting the clay to separate and flow to the center of the pool.

The failure did not occur without warning, but the great mass of earth slid out within five minutes after it started to go. There had been a slight horizontal movement of the upstream slope of the dam as early as June 18, 1917, whereupon sluicing was discontinued until Feb. 12, 1918, except for a period of 12 days in the summer of 1917. On March 4, three weeks after sluicing had been resumed, another slight horizontal movement of the upstream face occurred. Sluicing was again stopped, but 10 days later, March 14, the failure occurred.

The depth of the hydraulic fill in the center was 155 ft. at the time of failure. In five minutes 800,000 cu. yd. slid out, leaving about 2,000,000 cu. yd. still in place. The 2,000,000 includes the whole of the downstream part of the dam. At the time of the failure the reservoir was partly full, the water being about 55 ft. deep. The cost of replacing the upstream material will be more than $500,000. The original estimate of the cost of the complete dam was $2,500,000, and it was to have contained 3,085,000 cu. yds.

Beginning March 16, 1916, it was the practice to have a man periodically force a 1½-in. pipe into the hydraulic fill, and this practice was continued till Jan. 24, 1917, when the "ball test" was adopted. The material in the core was so plastic that the pipe could be forced down to a depth of 90 ft. On Feb. 12, 1917, the ball test was begun, and it was found that a 6-in. cast iron ball sank by its own weight 45 ft. into the soft clay fill, or half the depth that the pipe was forced. By July 27, 1917, the depth of penetration of the ball was 35 ft.; a month later it was 12 ft.; and on Jan. 21, 1918, it was only 5 ft. From this test it was apparently reasoned that the fill had dried out suffciently to be safe.

See Chapter XVIII for a description of the construction of this dam.

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CHAPTER XXI

DIKES AND LEVEES

This chapter relates solely to the design and construction of earth embankments along rivers, lakes and oceans, to exclude water from low lying lands. The reader is referred to Chapters VI and XX for data on making embankments water tight. For methods and costs of protecting embankments with brush mattresses and sheet piling, and for surfacing slopes with concrete and stone masonry, see the author's "Handbook of Cost Data."

The Location of Levees. This is discussed by Arthur A. Stiles, State Levee and Drainage Commissioner of Texas, in a report issued in 1913.

The problem involved consists in providing a channel for the flood flow of the stream. This can be done either by confining it to the usual channel between high levees or by increasing the channel section by building the levees away from the river.

It is a well-known characteristic of over-flowed river valleys that the ground surface, rising gradually from the base of the

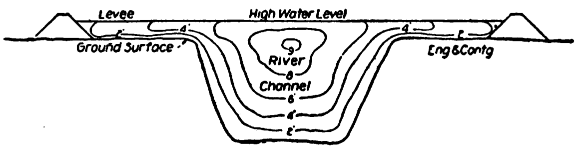

Fig. 1. Typical Cross-Section of River Channel, Showing Probable Distribution of Current Velocities in Ft. Per Sec. and Their Influence Upon Levee Positions.

foothills at each side of the flood-plain, reaches its greatest elevation at the banks of the channel overlooking the principle stream. Hence, a levee to be of minimum height and maximum protection should be built along this crest, but a stable position cannot be obtained so near the channel, and the distance which should separate the proposed levee from the adjacent stream bank may be regarded as the result of a compromise between practical interests, and other more technical requirements.

Fig. 1 shows the advantage of setting the levee back to where it will be subjected only to the wash of slow moving water.

Land lying between the levee and the normal channel is, in a way, wasted, as it should be kept clear to permit the passage of water. Where levees are built on a tidal stream fences of brush should be built across this waste land from levee to channel at frequent intervals. These will in time build up the waste ground so that it will form a considerable reinforcement to the levee.

Design of Dikes for Salt Marsh Reclamation. This is discussed in *Engineering and Contracting*, Sept. 6, 1911, as follows:

Dikes for tide marsh reclamation are made of earth, but they differ from the levees used on rivers in that they must be so located and designed as to withstand the action of the waves. The best protection against waves is to have the dike a safe dis-

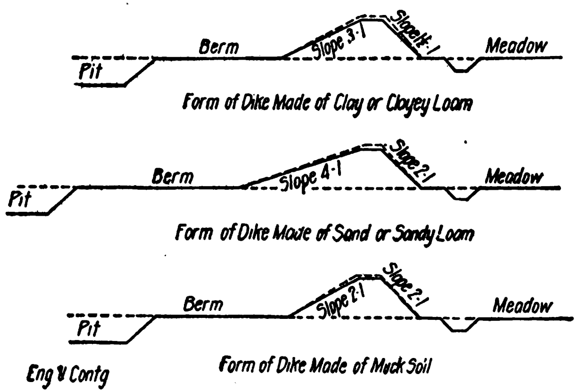

Fig. 2. Typical Dike Sections for Different Materials.

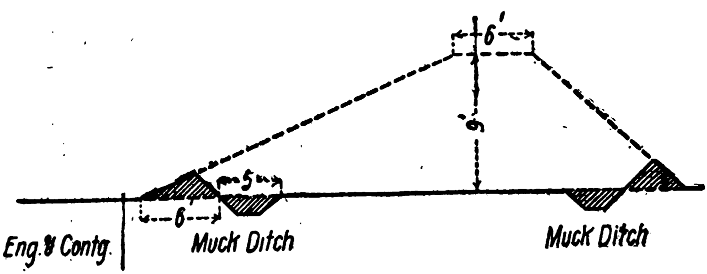

Fig. 3. Method of Preparing Base for a Dike.

tance from the shore, never less than the width of the base of the dike, and a greater distance if wave heights require it. The cross-sectional dimensions depend upon the material available for construction and the length of time the water will remain against the dike. Three forms of dike sections are shown in Figs. 2 and 3.

The ground is cleared and broken up under the base, and where very wet is frequently ditched along each edge of the dike about

6 ft. inside the toes, as shown by Fig. 3. The dirt from these ditches is used for the toes of the dike and the ditches themselves are filled with the new material from which the embankment is made. It is preferable practice to borrow the material for embankment from the water side. The borrow pits should be located well away from the toe of the dike.

Design of a Dike for Tidal Marsh Reclamation. *Engineering and Contracting*, Nov. 15, 1911, describes the reclamation of marsh land on a tidal stream at Cape Cod, Mass. A dike 900 ft. long, 22 ft. wide on top, was built. See Fig. 4. A roadway runs along the top of the dike the crown of which is at grade 17.7 ft. above mean low water, or about 7 ft. above ordinary high tide. The maximum bottom width is about 68 ft. The filling

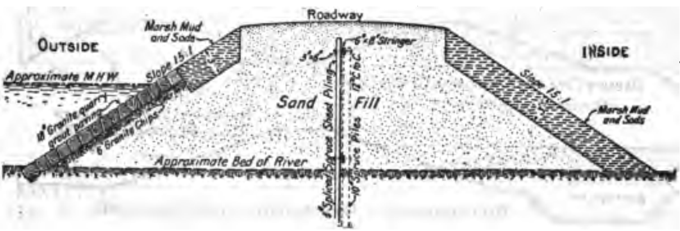

Fig. 4. Typical Section of Dike, Herring River Reclamation, Cape Cod.

was obtained from pits in the hills at each end of the dike, and was hauled in automatic side dumping cars of about 3 cu. yd. capacity. The 20-in. gage track was laid so that the cars ran out from the pit by gravity; the empty cars were pushed back on the level track along the dike by two men, and drawn up the grade to the pit by a rope and hoisting engine. The sand was placed at a labor cost of about 8 ct. per cubic yard, the haul being about 450 ft.

Along the center line of the dike from end to end 4-in. splined spruce sheeting was driven about 6 ft. into the river bed, the top of the sheeting extending nearly to the top of the dike. The upstream slope of the dike is backed by a 6-in. layer of granite chips. Some of the blocks in this facing weigh more than 3 tons, and the whole construction appears to be very safe and durable. Above the heavy facing the protection is the same as on the upstream slope. The top of the dike is surfaced with a mixture of fine sand and clay silt, and is sufficiently compact to make a fair roadway for light teaming.

Levee Sections on the Mississippi and Sacramento Rivers.

Fred H. Tibbitts, in *Engineering and Contracting*, Apr. 9, 1913, gives the sections shown in Fig. 5. The California levees are not subject to flood for such long periods as those on the Mississippi.

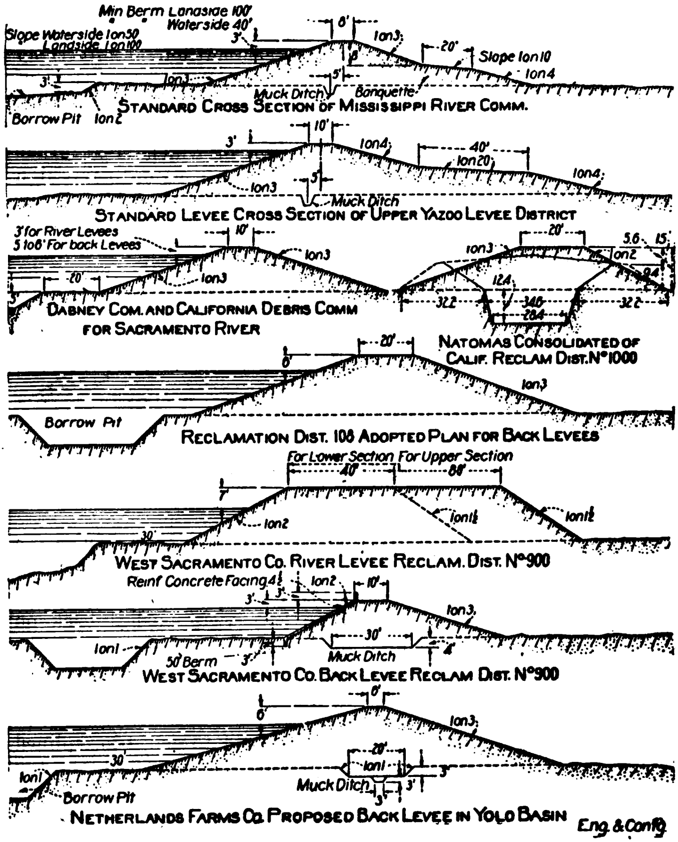

Fig. 5. Standard Levee Sections on the Sacramento and Mississippi Rivers.

They are subject to greater wave action, and, being built of sand, they have not been so generally successful as the levees on the Mississippi.

Enlarging and Slope-Walling a Levee on the Wabash River. This is described by George C. Graeter in *Engineering News*, Jan. 4, 1917. This levee was built in 1895 at a cost of $74,500. A total length of 8.6 miles of levee reclaimed 7,500 acres of bottom and marsh land which now has a value of $100 per acre.

In 1904, $4,000 was spent for repairs; in 1912, $18,300 for repairing breaks; and in 1913, $14,500 for repairing breaks and for placing concrete at the riverside toe of slope on 12,500 ft. of the upper end. Maintenance has cost $14,000 (or about $650 per year), most of this being spent in digging out ground-hog and mole burrows and mowing the levee. Thus the cost of repair and maintenance up to 1916 was over 66% of the first cost of construction, and the levee was still in poor condition.

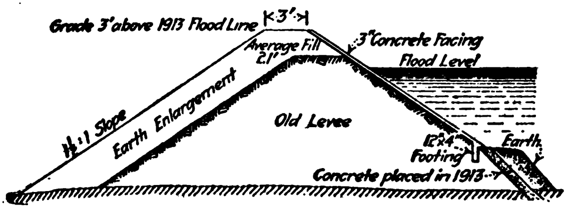

Fig. 6. Wabash River Levee Showing Earth Enlargement and Concrete Facing.

In 1916 the Levee Committee adopted a plan of raising the levee and facing it with concrete, see Fig. 6.

The concrete extends for about 12,500 ft. from Riverton to a sand ridge. It consists of 199,100 sq. ft. of facing and 154.3 cu. yd. of footing. The earth enlargement on this upper section averages 231 cu. yd. per 100-ft. station; on the next 20,000 ft. beyond this ridge it averages 163 cu. yd. per station, and then for about 6,700 ft. the average is 240 cu. yd. per station. The total enlargement, including a short stretch of relocated levee, amounts to 88,000 cu. yd.

On the section that is being concreted the earth enlargement (28,890 cu. yd.) is being put up by a reconstructed Monighan dragline excavator. The remainder of the enlargement is being constructed with teams, using drag and wheel scrapers. The shrinkage allowance was 20% for dragline work and 10% for team work. The top and land slope of the levee were plowed, and all stumps and brush were removed before placing the fill for the enlargement. The Levee Committee provided borrow pits without expense to the contractor. The specifications permitted ma-

terial to be taken on either side of the levee, but required it to be taken on the river side where possible. No material was to be taken within 22 ft. of the toe of the old slope, and new pits were not allowed to be more than 3½ ft. deep.

The contract prices for this work were 20 ct. per cu. yd. for earth enlargement and $6.60 per cu. yd. for concrete facing.

Levee Construction by Dragline Excavators on the Little River Drainage District, Mo. B. F. Burns, in *Engineering and Contracting*, July 18, 1917, gives the following:

For the main diversion channel and levee a strip is cleared approximately 400 ft. wide. From this all brush logs and débris are removed. The stumps on the berms are cut to 24 in. above the ground, but elsewhere they are cut to such heights as will enable them to be removed with stump pullers, stump pullers and skidders being a necessary part of the contractor's equipment. As the work goes forward the floodway strip, 900 ft. in width, is cleared and, before the final completion of the system, all logs, brush and débris are removed so as to permit of the free movement of the flood water over it.

Following the clearing of the channel and levee base area the stumps are broken with dynamite and removed and the roots grubbed out so that the material will be practically free from fibrous matter when excavated from the channel and placed in the levee.

The work was divided into two contracts. Contract "A" including that part from Allenville west, and contract "B" that part east of Allenville.

The operation of stripping and digging muck ditch on Contract "B," is done by caterpillar tractor having a boom length of 70 ft. and a bucket capacity of 1½ yd. The machine works over the channel area for a stretch of approximately 2,000 ft., removing the surface material for a depth of 6 in. or more, and depositing the same on the levee area at the limit of its boom reach. It then tracks back and begins stripping the levee base area, removing the surface material to about the same depth as on the channel, and placing the stripping outside of the levee base area and also removing that taken from the channel, which it places with the levee stripping. As the machine moves over the levee base area it excavates the muck ditch, 6 ft. wide and 8 ft. deep, and places that material along the outer toe line of the levee. As the levee is finished, the stripping, which is quite free from roots and other material objectionable for levee construction, will be shaped into a banquette of such height and with such crown as the material will make.

An experiment in the use of dynamite for the excavation of

muck ditches was made soon after the construction started. The muck ditch at that point was but 3 by 4 ft. The experiment was not successful as the ditch was unsatisfactory.

The character of the soil under the levees was determined by borings made to a depth of 11 ft., along the center line, at intervals of 300 ft. These borings indicated that at one point the soil was such that an ordinary muck ditch would not effectually cut off seepage. Further investigation showed the extent of that condition to but little more than 100 ft. along the center line of the levee, and, in lieu of a muck ditch, a wall of Wakefield sheet piling was driven. These were driven to a penetration be-

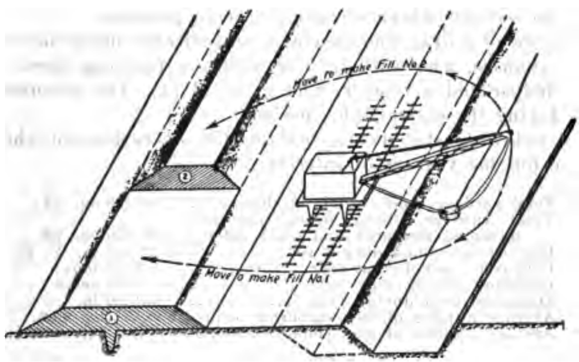

Fig. 7. Movement of Dragline Machines in Constructing Levees.

low the sandy strata and allowed to protrude 4 ft. above the surface, penetrating the levee to that extent.

Two machines are required to excavate the main diversion channel.

On Contract "B," the first machine is a Bucyrus drag line, having a 125-ft. boom and a 3½-yd. bucket. This machine tracks along the channel near the center line and excavates approximately 65% of the material. This it places over the levee area in layers about 8 ft. in depth, making two lifts. In depositing the material for the first lift, the movement is clockwise and in placing the second lift it moves in the opposite direction. See Fig. 7. The earth is compacted by dropping at least 8 ft.

The second machine, a Bucyrus drag line, 100 ft. boom, 4-yd. bucket, tracks along the berm and removes the remainder of the material in the channel. It likewise deposits the material in two lifts and operates in the same manner as machine 1. Usu-

ally machines 1 and 2 are at least 2,000 ft. apart. Machine 2 carries the levee to its shrinkage grade and section.

The operations on Contract "A" are similar to those on Contract "B," with the exception that the stripping is removed and muck ditch excavation is made by the pilot machine, which also excavates about 30 per cent of the channel. Two Bucyrus drag lines, 100-ft. booms, 3½-yd. buckets, are in use on this contract.

The material handles more easily if there is some water in the channel, but, if there is too much, it makes the material unstable for levee building and slides result. Except during periods of heavy rain, the stage in the channel is controlled by pumping, dams being left in the channel at intervals and the water pumped from the sections where operations are in progress.

The crew of a drag line excavator, electrically operated, consists of the runners, who work in 8-hr. shifts, a foreman, three laborers, a helper and a spotter, who work 12 hr. The machines operate during the entire 24-hr. period.

The following statement, covering the operations of the contractor for one year, is of interest:

Total yardage, four electric machines.....	2,682,330 cu. yd.
Total yardage, three steam machines, including stripping and muck ditch..	980,750 cu. yd.
Current consumed during year	1,952,240 K. W. H.
Coal consumed during year	4,350 tons
Grubbing during year	155 acres
Dynamite used during year	133,000 lb.
Average number of men employed, contract "A,"	102 men.
Average number of men employed, contract "B,"	187 men.

The above indicates that under similar operating conditions it requires 0.756 K.W.H. per cu. yd. to excavate earth, and that 0.9 lb. of coal is required for the same purpose.

Levee Construction in Texas with Draglines. In *Engineering and Contracting*, July 17, 1918, O. W. Finley gives the following:

The first levee work of any magnitude on the Trinity River in northern Texas was begun in June, 1914, when a levee 10 ft. high and 44,000 ft. long was built for the protection of 9,040 acres of very fine black flood land in Kaufman County. This levee has since been raised to 18 ft. height. The levee was constructed by an old steam skid and roller dragline machine which has long since been junked and has now been replaced by 18 new machines, 15 of which are Monighan gas walking machines, one a Bucyrus mutipedal, one a gas skid and roller and one a steam skid and roller. The 18 machines are of the following types and sizes:

All the small machines have vertical triple cylinder gas engines while all the larger or No. 2 and 3 machines, except the Bucyrus, have horizontal single cylinder gas engines. The Bu-

cyrus has a triple vertical type engine and is an excellent dirt mover.

Up to May 18, 1918, a fraction more than 100 miles of levee had been built in which had been placed 6,540,000 cu. yd. of earth. Seldom more than 15 of the machines are working at the same time, the others are moving from one job to another, but nearly 500,000 cu. yd. are being moved per month, or an average of about 30,000 yd. for each machine. The larger machines sometimes excavate more than 60,000 yd. a month.

The contract price for these levees is about 10 ct. per cu. yd. The cost per acre for reclamation varies from $14 to $70. It is stated that these lands are so valuable for agriculture that expenditures up to $100 per acre are justifiable.

Machines for Building Levees. J. R. Slattery in *Engineering News*, May 25, 1916, gives the following: The floods of 1912 and 1913 resulted in a number of crevasses in the Mississippi River levees which it was imperative to repair before the next flood period. Recognizing the inability of existing team outfits on the river to handle this work economically, the Mississippi River Commission directed that careful consideration be given to the problem of selecting suitable mechanical devices for levee construction.

TABLE I.—AMOUNT AND YARDAGE COSTS OF MISSISSIPPI RIVER LEVEES

Fiscal year	Cu. yd.	Price per cu. yd.
1882–90	1,672,619	28.83
1891–92	979,154	22.37
1892–93	793,365	21.12
1893–94	785,642	17.50
1894–95	1,326,255	11.19
1895–96	1,149,411	9.26
1896–97	256,153	11.70
1897–98	4,141,326	12.67
1898–99	2,845,342	11.67
1899–1900	1,840,340	17.30
1900–1901	614,940	13.52
1901–2	21,932	18.56
1902–3	841,589	17.21
1903–4	1,905,842	17.24
1904–5	1,040,708	17.40
1905–6	429,632	19.75
1906–7	305,507	21.89
1907–8	918,504	20.55
1908–9	986,674	25.31
1909–10	303,878	22.08
1910–11	906,761	20.34
1911–12	420,260	11.64
1912–13	1,072,305	25.80

Specifications for levees above the Red River require that borrow pits shall be 40 ft. from the base of the levee on the river side and 100 ft. from the base of the levee on the land side. Side

slopes of borrow pits must be very flat. Below the Red River borrow pits may be within 20 ft. of the base of the levee on the river side and within 80 ft. on the land side.

The generally smaller levees below Red River and the more liberal pit specifications for them made the selection of a suitable type of machine for their construction much less difficult than the selection of a machine for levees above Red River. The machine selected was the dragline excavator, of the self-contained, revolving locomotive crane type, arranged to operate an orange-peel, clamshell or drag-line bucket at a radius of 90 or 125 ft.

The machines are mounted on four-wheel trucks and are provided with the necessary mechanism for performing the operations of traveling and hoisting, rotating and operating a bucket. Track is provided for the machines to work on during low-water stages and barges from which to operate them during high-water stages. The barges are likewise used to transport the machines from one job to another. The crews of the machines are housed on quarter-boats. The first machine with its barge, quarter-boat, track and equipment cost approximately $40,000. The second and third machines purchased are stronger and of greater capacity than the first one, and the last machine purchased has been so successful as to warrant its adoption with minor modifications as a type for work in the Fourth District, particularly below Red River. This type machine will handle a 3-yd. orangepeel bucket or a 5-yd. dragline or clamshell bucket at a radius of 126 ft. from the center of the machine. The cost of machines of this type fully equipped and provided with a quarter-boat for the housing and care of crew and coal barge for supplying it with coal will be approximately $60,000. This figure does not include the cost of a barge from which to operate it during high stages and with which to move the machine from point to point. The cost of a steel barge suitable for this purpose is about $18,000. It will not be necessary to provide a barge for every machine. It is thought that with these machines it will be possible to place earth in the levee system, wherever rehandling is unnecessary, at field costs of from 5 to 10 ct. per cu. yd., exclusive of the cost of clearing and grubbing when this is necessary. When material can be placed in the levee without rehandling this type of machine is believed to be the most economic for levee work.

Above the mouth of the Red River the levees become much higher than below the Red, and this fact, together with the more difficult pit specifications, necessitates greater reach on the part of the machines. The considerably greater reach led to the selection of cableway machines for trial in preference to drag-line machines.

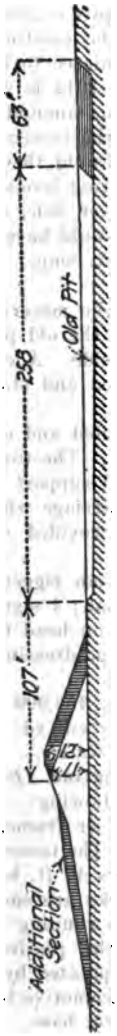

Fig. 8. Average Enlargement of Levees Above Greenville, Miss.

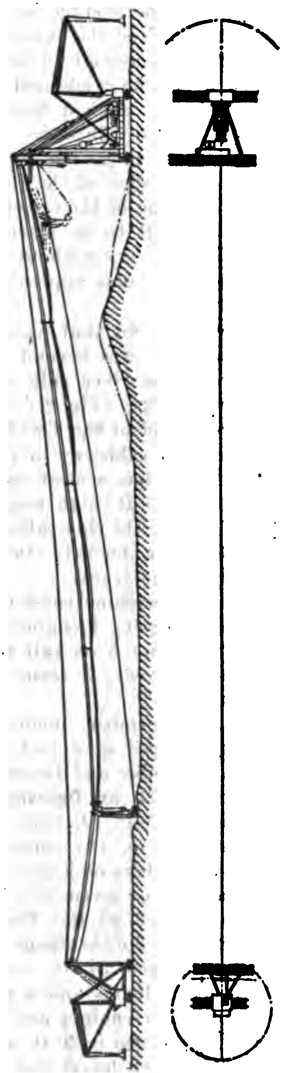

Fig. 9. Lidgerwood Dragline Cableway Excavator Used to Build Mississippi Levees.

Above Greenville the average height of the levee system is 20.7 ft.; the average width of the existing riverside pits is 258 ft.; the average amount of material to be added to the existing levees to bring them up to the grade and section calculated to be necessary to contain safely such a flood as that of 1912 is 2,150 cu. yd. per 100 ft. station. In order to obtain this amount of material it is necessary to go out 63 ft. beyond the existing riverside pit. The outer edge of the resulting pit would then be 428 ft. from the center line of the crown of the existing levees. Even if this earth were all to be placed on the river side, dragline excavators to do this work without rehandling would have to handle their buckets on booms approximately 200 ft. long. See Fig. 8.

A machine was sought that would take all the material from the river side of the levee beyond the limit of the old pits, and place it either on the river side or the land side. A cableway of the Lidgerwood type (Fig. 9) was purchased and started to work on the upper end of the Third District.

The first cost of a cableway of this type erected and equipped is about $45,000. It has a clear span of 662 ft. The towers are of steel, 85 ft. and 45 ft. high respectively, and support between them a 2¼-in. cable. On this cable travels a carriage which carries a 3-yd. dragline bucket. Derricks are provided on each tower for handling the track.

The crew of this machine consists of 1 foreman rigger; 1 operator; 1 rigger's helper; 1 engineman; 1 fireman; 1 signalman; 8 laborers; (trackmen) 3 on tail tower and 5 on head tower, 3 laborers (dressing levee), 3 teamsters (plowing, dressing levee, and hauling supplies).

From April to December, inclusive, in 1915, 153,900 cu. yd. of material were placed at a cost of 15 ct. per cu. yd. Delays were caused in September and December by high water.

Levee Building with an Oglesby Tower Dragline. *Engineering and Contracting*, May 12, 1915, gives the following:

The main tower (Fig. 10) consists of a timber frame, 78 ft. high of 10 x 14-in. timbers on a 24 x 27-ft. base. The tower is supported on a platform of seven 12 x 16-in. timbers 40 ft. long laid on wheel trucks spaced 32 ft. The wheel trucks are each composed of four 20¼-in. double flange, iron wheels running between two 12 x 16-in. timbers 24 ft. long. Upon the platform are mounted three 60-in. drums and a pony drum operated by double 12¼-in. by 15-in. Flory engines and a 150-hp. locomotive boiler.

The operator's platform is 26 ft. above the tower base. Control is secured through seven levers and six pedals connected with the drums by pipes to the platform. The dragline sheave may be

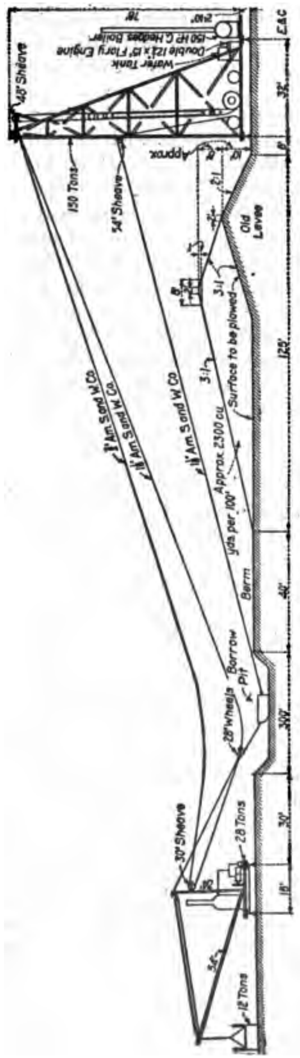

Fig. 10. Method of Operating Oglesby Excavator.

raised and lowered to suit varying heights and slopes of levee. The slack cable and tail rope operate over sheaves at the top of the tower. The cableway is attached within the tower to a throw wheel double block, the rope from which leads over the central drum.

The tail tower consists of a platform 20 x 20 ft. laid on five 12 x 12-in. by 20-ft. timbers supported on two three-wheel trucks spaced 16 ft. The gallows frame is 24 ft. high and the counterweight boom 24 ft. long. Timber seats are used for both the gallows frame and the boom. The boom seat is slightly rounded to the segment of a circle having a cord of about 6 ft. and a middle ordinate of about 8 in. This joint is unique and bears an important part in facilitating the movement of the tail towers, as described later. A vertical boiler and second-hand hoisting engine are mounted on the platform of the tail tower. The counterweight consists of a timber box filled with earth.

This tail tower is a loose jointed structure and has an important function in absorbing shocks occasioned by sudden stoppage of the bucket. It acts as a safety valve in the operation of the machine.

The dragline and slack line cables are 1⅛ in. in diameter and the tail rope is ¾ in. diameter. These cables have handled 154,000 cu. yd. of earth up to the present time and very little wear is apparent. No trouble of any kind has been experienced with the cables. In this connection the sheave arrangement is worthy of note.

Bucket. The bucket was designed by C. G. Oglesby and made in Memphis, Tenn.

The average time required for a round trip of the bucket from the back of the borrow pit is 3 minutes. As a rule the bucket pushes about 1 cu. yd. of earth in front, some of which falls off and builds up the berm. The amount of earth moved in a trip varies from 5 to 9 cu. yd. The average bucket load of a day's run is probably 6 cu. yd.

For dumping, the elevation of the dragline sheave has been so adjusted that the teeth of the dumped bucket follow naturally the face of the 1 to 3 levee slope. This facilitates the use of the bucket in dressing the levee face. The bucket is dragged over the earth already placed in the levee to the dumping point. The compaction resulting from the repeated passage of the loaded bucket, the average weight of which exceeds 15,000 lb., is an important factor in securing a stable levee.

When the earth is wet the three stage method of placing is employed as shown in Fig. 11. Ordinarily the earth is placed the full height for each runway.

Two men with shovels are employed, finishing and smoothing the earth placed in the levee. If the earth is quite wet when placed and drys out in clods, a Mormon scraper is used to advantage in smoothing.

The costs given here are not representative of the cost of handling earth with the Oglesby machine since they include the cost of developing the machine to its present state. The costs given, moreover, do not include accurate repair or construction costs on the machine or the contractors' overhead cost. These costs are, however, estimated at $25 a day. The operating costs it is believed by Mr. Oglesby could be materially reduced by increasing the boiler capacity and thereby reducing the coal loss resulting from the use of forced draft on the present boiler and by using a 10-cu. yd. bucket. The amount of earth to be moved on the job does

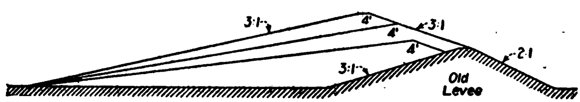

Fig. 11. Stage Method of Building Levee When Earth Is Wet.

not, however, justify these changes. Table I gives the daily operating cost of the excavator.

The machine has operated up to Apr. 20, 1915, a total of 1,914 hr. and has built 154,031 cu. yd. of compact levee, an average hourly output for the whole job of 80 cu. yd. The best day's work was on April 18, and amounted to 1,610 cu. yd. of compacted levee, a length of 70 ft. On that day the cost of building finished levee was approximately 8 ct. a cu. yd.

It must be borne in mind when comparing the costs of this work with team work that the average haul for wheelers would be not less than 400 ft. The machine is essentially long haul, shallow pit type of excavator.

The machine was erected early in 1914, and, after numerous delays incidental to the development of a pioneer machine, was well started Sept. 1, 1914. Work was interrupted by high water on the Mississippi for a month in 1915. On April 20, 1915, a total of 154,000 cu. yd. had been moved and it is estimated the job will be completed by Aug. 1, 1915.

The daily (12-hr.) cost of operating the excavator was:

1 foreman at $150 a month, 20 days	$ 7.50
1 runner at $150 a month, 20 days	7.50
3 trackmen at $2	6.00
1 fireman	3.00
1 tail tower engineman	3.00
1 tail tower helper	2.00

2 levee trimmers at $2.50	5.00
1 extra man	2.00
1 pump engineman	2.50
1 team and teamster	5.00
1 night watchman	2.50
Total daily labor cost	$ 46.00
Fuel.	
7 tons coal (on 3 boilers) at $7.75	54.25
Oil and waste	1.50
Total daily labor and fuel cost	$101.75
Repairs, depreciation and overhead expenses estimated for normal conditions	24.00
Total daily operating cost	$125.75
Output April 11–20, 100 hr. operated, compacted levee, cu. yd.	8,754
Earth actually placed in levee, allowing 25% shrinkage per 12-hr. day, cu. yd.	1,340
Approximate cost per cu. yd. compacted levee, ct.	11.7
Approximate cost per cu. yd. earth moved (no shrinkage), ct.	9

Building Levees with a Hydraulic Dredge. In *Engineering News*, Oct. 29, 1914, appears the following by Jean M. Allen:

Sand or gravel dredged by the hydraulic process is not carried entirely in suspension by the water in the discharge pipe, but the heavier material settles and flows along the bottom at a velocity much lower than the impelling water. This is specially true if the pipe line is long or the velocity of the discharge water is low. This action can be utilized to build embankments of as steep a slope as 1 on 1, directly from the discharge pipe.

This is accomplished by what are called "shutter pipes," which are lengths of ordinary slip-joint discharge pipe, generally made of No. 10 to 14 sheet steel and in lengths of from 16 to 18 ft., with openings in the bottom. (See Fig. 12.) These openings are controlled by steel plates or shutters and may be opened or closed at will. A stretch of these pipes is laid on a trestle and the discharge pipe from the dredge is connected to them. When the shutters are opened the sand flows at about the consistency of thick mortar, building up into a steep embankment.

The discharge pipe is continued beyond the shutter pipe in order to carry away the surplus water and avoid washing down the levee which has been built. The shutters should be spaced 3 to 4 ft. apart, and should be attached to the pipe with chain or wire, otherwise many will be dropped into the fill and lost.

Many sizes and types of dredges have been used, with discharge pipes 12 to 20 in. in diameter, and the cost of the complete plant is from $15,000 to $100,000. Both steam and electrically driven dredges are being used. Some have revolving cutters or water jets to disintegrate the material, but many have neither appara-

tus. This depends on the compactness of the material to be excavated. In general, any attempt to economize in first cost at the expense of construction or equipment of the dredge will be paid for dearly in subsequent breakdowns and loss of time.

Mississippi and Missouri River Dredges. On these rivers, 12 and 15-in. dredges are used, due no doubt to the reluctance of the contractor to build an expensive plant for the small yardage of contracts offered.

The total cost of a 12-in. plant, complete with pipe line, is between \$15,000 and \$25,000, depending upon the class of machinery and the refinement of construction. Between 25,000 and 50,000 cu. yd. per month would be the probable output, depending upon

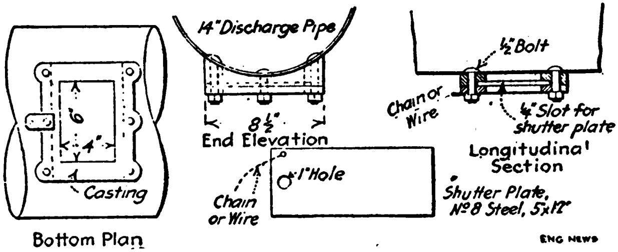

Fig. 12. Bottom Discharge Gates for Shore Pipes of Hydraulic Dredge.

the length of the pipe line, the layout of the work, river conditions and the skill of the operators.

The dredge with 15-in. pump is built along the same lines as the 12-in., though frequently the pump is directly connected rather than belt driven. In either case, the engine should be compound, to save fuel. Between 250 and 300 hp. is required for a plant of this size, depending upon the conditions mentioned. An efficient engine for medium power is a cross-compound of either the horizontal or marine type. The boilers should have about 2,500 sq. ft. of heating surface. If surface condensers are installed, water-tube boilers may be used, otherwise the Mississippi River type is to be preferred. A donkey boiler should be provided for washing the main battery. A hoisting engine handles the suction pipe, but it is desirable to have a deck capstan with independent engines for handling the boat.

The suction pipe is articulated at the end of the dredge either by a swivel elbow or merely by a length of suction hose, and is raised and lowered by tackle suspended from an A-frame over the bow. Its lower end is provided with a suction nozzle, consisting

of a cone-shaped head with cross bars to prevent the entrance of large stones and pieces of wood that would clog the pump. The hull will be about 110 x 30 x 5 ft. The 15-in. dredge, complete with all equipment, will cost between $25,000 and $45,000 and its output will be from 60,000 to 125,000 cu. yd. per month. To attain the latter figure, the conditions must be very favorable and the dredge must be operated continuously (24 hr. a day) and with very few delays.

The maximum monthly output of which a dredge is capable is rarely attained in levee work, on account of the large percentage of time lost in shifting pipe, and it is of great importance that experienced men be employed, to reduce this loss to a minimum. As the shutter pipes have to be shifted ahead as each section of the levee is completed, it is advisable so to plan the work that operations can be conducted on two sections simultaneously. The main discharge pipe is provided with a Y-branch and gate valves so that the filling can progress on each section alternately, thus reducing the idle time of the dredge. If this is not possible, sometimes the levee is brought up to the full height but not to full width at the first operation, and then widened with the branch line while extending the main line.

Some contractors use a discharge pipe of larger size than the pump and suction; for instance, an 18-in. discharge pipe for a 15-in. pump, with 15-in. suction pipe. The purpose is to save power by reducing the velocity of water in the line and thus the friction head pumped against. But it is the velocity rather than the quantity of the water that is instrumental in keeping in suspension and transporting such heavy material as coarse sand and gravel. Enlarging the discharge pipe reduces the velocity and causes the sand to settle until the cross-section is reduced and the velocity thus increased to a point where it will again carry the material.

It is better practice to use a discharge pipe of the same size as the pump as far as it connects with the shutter pipe. There it may be enlarged, as it is desired that the sand should settle so that it may be discharged through the shutters. In a high-powered 20-in. dredge on the New York Barge Canal, difficulty was experienced in pumping gravel and small boulders through a long 20-in. discharge line, but upon replacing this with a 16-in. line the material was discharged with ease and the output greatly increased.

Shields or slope-boards, consisting of plates of No. 16 steel about 10 ft. long and 18 in. wide, are frequently used to facilitate the formation of the desired slope. A number of these are inserted, end to end, in the partly formed slope. They prevent

the sand from flowing downward until it fills to the top of the plates, when they are pulled out and moved further up the slope.

The hydraulic construction of levees requires considerable skill. The suction-pipe operator must keep a steady and uniform flow of sand in the discharge pipe, and the pipe men must use judgment in opening and closing the shutters to build the embankment to the proper slope; closing some of them if the percentage of sand in the pipe decreases and opening enough of them to discharge water if the slopes need to be flattened out. The handling of the slope boards also requires practice. With a good reliable plant, properly designed to meet local conditions, some remarkable results have been obtained, not only in the low cost per yard but in the character and appearance of the fill.

The monthly operating costs given in the accompanying table are typical for a 15-in. dredge on the Mississippi River:

1 foreman	$ 150
1 engineman	125
1 engineman	100
2 suction operators, at $100	200
2 oilers, at $60	120
2 firemen, at $70	140
2 coal passers, at $60	120
3 deck hands, at $60	180
1 levee foreman (day)	90
1 levee foreman (night)	70
10 levee laborers, at $60	600
26 Total labor cost per month	$1,895
Coal (18 tons per day)	1,200
Supplies (rope, oil, packing)	150
Repairs and renewals	200
Office and overhead expenses	200
Insurance (fire and liability)	100
Interest and depreciation (2% on $35,000)	700
Total operating cost per month	$4,445

This is for two 12-hr. shifts daily. The wages do not include subsistence. Assuming an output of 75,000 yd. per month the cost is about 6 ct. per yd.

Construction of Levees by Hydraulic Dredges. D. L. Yarnell, in *Engineering News*, June 11, 1914, describes work on levees on the Mississippi River near Trempealeau, Wis., and in Henderson County, Ill., as follows:

Each of the dredges consisted of a hull 24 x 80 x 4½ ft., upon which were mounted a centrifugal pump having one 12-in. suction pipe and a 14-in. discharge pipe, a 200-hp. engine, and a boiler nominally rated at 150 hp. The discharge pipe was carried from the dredge to the top of the levee by small towers mounted on 14 x 40-ft. barges. The power actually developed by

the engine varied with the length of the discharge pipe, the height of delivery and the character of the material pumped.

The desired slopes were formed by means of steel boards about 18 in. wide and 10 ft. long, of No. 14-gage steel with angle-iron top, not too large or heavy to be easily moved by one man. The slope boards are placed at the intersection of the side slope with the natural slope of the end of the fill under construction. Several men equipped with shovels are necessary to distribute the material evenly and to move the slope boards ahead as the levee is built up.

In the Trempealeau District, there were two separate levees constructed. The levees were built with material from the channel excavated to divert Trempealeau River from near the foothills to Trempealeau Bay. The average width of the levee crown is between 8 and 10 ft., and the average height of embankment is probably 14 ft. The levees have slopes of 1 on 3 on the water side and 1 on 2 on the other, with banquette against the land side upon which is a roadway. The site for the levee was not cleared of vegetation and stumps were not grubbed out for the reason that during the greater part of the construction period, the bed of the levee was flooded. It was assumed that the method of construction so completely sealed the voids around the stumps that moisture enough will be retained and the air excluded to prevent decay. The total earthwork in the two levees and diverting channel is approximately 500,000 cu. yd., which was let at a contract price of 8.5 ct. The construction work was begun in May, 1912, and completed in October of the same year by the La-Crosse Dredging Co., two dredges being used.

Part of the levees in Henderson County, Ill., drainage districts Nos. 1 and 2 are being built by hydraulic dredges. The levee of District No. 2 is a reinforcement placed against the west side of the C., B. & Q. R. R. (Carthage Branch) embankment, carried about 3 ft. higher than the track. The easterly slope of the new fill is 1 on 1½, and the slope on the water side is 1 on 2½. About 126,382 cu. yd. have been let at a contract price of 15.9 ct., 23,400 yd. at 20 ct., and there is an additional 5,900 yd. for which contract has not yet been let. On the District No. 1, two sections of the levee are to be constructed with a suction dredge. The total length of these two sections is 20,500 ft.; the embankment is to have an 8-ft. crown and 1 on 3 slopes on both sides; the contract price is 11.25 ct. per cu. yd. The rest of the levee, incuding probably two to three times the amount of earth-work, with 6-ft. crown, 1 on 3 slope on the water side and 1 on 2 slope on the land side, is to be constructed with a dragline excavator at 12.1 ct. per cu. yd. The advertised earthwork, based on a 6-ft.

crown throughout the entire length and combined slopes of 1 on 5, was 821,400 cu. yd.

At the time of the inspection, the levee being built was about 14 ft. high, and the top width was 2 to 3 ft. wider than the 8 ft. specified. The designed section of the levee at that point contains practically 26 cu. yd. to the linear foot, and the constructed section about 27 cu. yd. On the day of the inspection, Aug. 23, the two 11-hr. shifts built 100 lin. ft. of completed levee, or 2,700 cu. yd. were actually placed. There were no delays for repairs, moving dredge, or any other reason. On this work a strip about 30 ft. wide in the base has been grubbed and ploughed, the entire base being cleared. The number of men usually employed was about 14, and the fuel used about 5 tons of good Illinois coal, in each shift. The average day's work will be considerably less than this, and to the cost of labor and fuel must be added that of delays, repairs, depreciation of plant, preparation of site, superintendence, and overhead charges.

A 20-ft. head with about 600 to 800 ft. of discharge pipe is the maximum condition under which a plant developing only 200 hp. can operate; greater heights and distances may be overcome by a corresponding increase of power equipment. The dredge must always be in about 8 ft. of water to prevent air from being drawn into the suction pipe. A dredge of this type costs approximately $15,000, not including the discharge pipe, the barges, and other necessary appurtenances, which will add about $5,000, making the total first cost about $20,000 for a plant to build levees by this method. It would hardly pay to put such an outfit on a contract of less than 250,000 cu. yd.

Building Levees in Ill. by Hydraulic Dredging. Jean M. Allen, in *Engineering and Contracting*, Feb. 16, 1910, gives a description of the method of filling low areas at Cairo, Ill. This work was particularly interesting because the material pumped into the fill by the hydraulic dredges was sand which is not used for filling low places as often as is clay or alluvial mud. Furthermore, the Cairo plant was unique in that the flow of material through the very long pipe line from the dredge was accelerated by the use of a booster pump.

The method used for building up the levee enclosing the dredged material was also unique. The tendency of the sand to settle in the bottom of the pipe permitted the building of levees having any desired slope, ranging from that assumed by moist sand to the slope of a semi-fluid. It was observed at Cairo that the gravel dumped from the openings nearest the pump was coarsest and that the material became finer as the distance it was carried increased. The method used in hydraulic fills of placing boards

as retainers on the slope was here used until it was realized that as sand was less inclined than clay to hold moisture, boards were not required. The regulation of the gate openings controlled the solidity of the fill. Even where mud is used for filling, sand might be efficiently employed to form retaining embankments if obtainable by dredging in sufficient quantities. Sand also settles much more quickly than does clay alone after being pumped. The addition of a certain amount of sand to clay embankments formed by dredging or hydraulicking would cause a quicker settlement of the material and would likewise improve the character of the fill.

Regarded as a hydraulic filling proposition some rather unusual and difficult problems presented themselves. The extreme distance to which the material was pumped was something over 6,500 ft. and the greatest elevation to be overcome at extreme low water was about 38 ft. Extreme low water was about 5 ft. referred to zero on the government gage at this point and the city grade was 43 ft. referred to the same gage. As it was intended to use 12-in. pipe and as a velocity of water of at least 10 ft. per second had to be maintained to keep the heavy sand and gravel in suspension, a total friction and static head of about 300 ft. had to be overcome.

There were very few data available on a plant of this kind. Some of the builders of standard dredging pumps declared that the proposed heads were excessive and declined to submit bids on the equipment. A somewhat similar plant found working in Kansas City, was carefully studied and much valuable information gained therefrom.

The following was the plant eventually decided upon and installed: A floating dredge was installed in the Mississippi River adjacent to the sand bar. It was connected to the bank by a pile trestle extending into the river a distance of 100 ft. and by a rigid pontoon line 160 ft. long connecting the boat with the trestle. Articulations at the connection of the trestle with the pontoons and of the pontoons with the bow of the boat enable the suction pipe, located at the stern of the boat, to pump sand from any point in the interior of a semicircle whose radius is 380 ft.

On the boat was installed a 12-in. centrifugal dredging pump of a standard make with a 32-in. runner. This pump was belted to a 20 x 24-in. slide valve engine. Three "Mississippi River" boilers, each 44 in. in diameter and 22 ft. long, supply steam at a pressure of 140 lb. To save time necessary to construct a hull for the dredge a river tow boat 141 ft. long, 26 ft. beam and 4½ ft. deep was secured and the dredging machinery placed upon it. The boat's original boilers, feed pumps and capstans were utilized

in the dredging equipment. The suction pipe passed over the stern of the boat and was raised and lowered by a small hoisting engine. In high water periods this suction pipe was about 50 ft. long.

A shore pumping plant, or "booster" plant, was located just inside the levee at a distance of about 1,800 ft. from the boat. The pump and engine were duplicates of those on the boat. Steam was furnished by two standard tubular boilers 76 in. in diameter and 16 ft. long. The discharge pipe from the boat plant connects directly to the suction of the shore plant pump. Both boat and shore plant used the Mississippi River water for boiler feed and both plants ran non-condensing.

The length of the pipe line from the shore plant to the discharge was about 1,300 ft. when the filling commenced and was increased to 4,400 ft. with the progress of the work. All pipe used except the suction and pontoon pipe was 12-in. spiral riveted pipe, asphalted. Nearly all the pipe was No. 12 gage, but on the end of the discharge line where the pipe required frequent handling and lightness was a prime consideration, some No. 14 and 16 gage is used.

A private telephone line connected the boat, shore plant and end of discharge pipe, and by it the suction operator was kept constantly informed as to the percentage of solids carried in the water and is thus enabled to regulate the supply. The surplus water found its way to the river by means of the city sewers.

The original estimates of the cost were somewhat exceeded and $42,000 was expended on the plant before it was ready for operation.

Pump Wear. The plant was started late in the season of 1907. A number of difficulties developed after the plant had been in operation a short time. The most serious was the rapid wearing of the shells of the dredging pumps. These were of cast iron and not very thick and it was found that every 15,000 cu. yd. pumped required a new set of shells at both the boat and the shore plant. This extreme wear was due in part to the quality of the material handled. The Mississippi River sand is very coarse and sharp. The high speed at which the pump had to be driven caused the shells to cut out faster than most sand pumps. It was found that, at low water periods and when pumping to the most distant areas a peripheral speed of the runner of about 5,500 ft. per minute had to be maintained to produce the required velocity in the pipe. Considerable trouble was experienced with the pump shafts as they wore very fast in the stuffing boxes and finally broke. As the pumps were of the side suction type great trouble was experienced in caring for the end thrust of the runner.

A great deal of time and money was spent in the endeavor to produce a pump more suitable for the work. Pumps with larger diameter runners, and with renewable liners in the shells were tried and at length a pump was evolved that gives very good satisfaction. The pumps finally used which were designed and built specially for this work, were of the double suction type to obviate the end thrust. The runners were built up of steel casting and ¾-in. boiler plate and were 52 in. in diameter. The shaft was 6 in. in diameter. The shells were concentric with the shaft and are heavy steel castings. The inside dimensions were 6 ft. in diameter and 10 in. wide. The metal in the shells was 1½ in. thick on the sides and 2 in. thick on the circumference. These pumps gave excellent service. A pair of them pumped 80,000 cu. yd. of sand, and it was estimated that a pair of the steel shells would deliver 200,000 cu. yd. before wearing through.

The 22-in. belts connecting the engines and pumps gave a great deal of trouble. Rubber and leather belts were tried, but none would stand the severe service. At last a wire rope drive was installed in both plants. This drive consisted of the ordinary grooved pulleys and ten parts of ¾-in. wire rope. Each strand of the wire was served with marlin which produced a very flexible rope. This transmission gave excellent service and caused no trouble since its installation.

Average Output and Cost. The periods of unusually high and low water experienced the last two years proved a great handicap to the work. At the extreme low water, which lasted for two or three months in the fall of the year, the sand bar was entirely dry and the boat was aground and could not be moved to secure a supply of sand. Again at high water, which was sometimes 45 ft. above low water, the land outside the levee and the trestle work to which the pontoons connected was from 6 to 10 ft. under the water. The running ice which filled the river during January and February was dangerous. These conditions rendered it necessary to suspend operations for at least six months out of the twelve. The plant averaged about 30,000 cu. yd. per month when running, and, up to the beginning of 1910 about 340,000 cu. yd. were moved.

A set of observations of the working conditions were taken December 4, 1909.

BOAT

Engine	132 R. P. M.
Pump	352 R. P. M.
Indicated horse power	321
Pump suction	15 in. vacuum
Pump discharge	60 lb. pressure
Steam pressure, boiler	138 lb.
Coal consumption	About 1 ton lump per hour

SHORE PLANT

Engine	140 R. P. M.
Pump	384 R. P. M.
Indicated horse power	365
Pump suction	4 lb. pressure
Pump discharge	82 lb. pressure
Steam pressure, boiler	130 lb.
Coal consumption	About 0.7 lb. screenings per hour

The velocity of the water was not determined accurately, but was about 10 ft. per second. The percentage of solids carried was also difficult to determine for the reason that a few hundred feet away from the pumps the sand settled to the bottom of the pipe, and while from 10% to 20% of the cross sectional area of the pipe may be filled with sand, this sand travels at a much slower velocity than the water. The average amount of solids delivered per hour was about 65 or 70 cu. yd.

About 16 men were required on the day shift and about 14 on the night shift. The weekly pay roll amounted to about $500. An extract from the report of October, 1909, is an average performance and is as follows:

Total yardage pumped	33,577.9
Total hours run	515
Yards per hour	65
Expenses —	Per cu. yd.
Fuel	$0.0482
Labor	0.0599
Repairs	0.0082
Oil	0.0022
Office and sundry	0.008
Total per cu. yd.	$0.1265

This statement makes no allowance for interest, depreciation nor insurance.

The contract price on the above work was from 24 ct. to 30 ct. for the railroad work and from 28 ct. to 44 ct. for the city work — the latter payable in bonds.

Shutter Pipes. A feature of the work of interest was the method used in building the levees to confine the material within the desired areas. At first the levees were thrown up of earth by means of slip scrapers, but later they were built of sand directly from the pipes by what are termed "shutter" or "slide pipes." A number of lengths of the regular discharge pipe were provided with openings on the lower side about 3 x 4 in., the 4-in. dimension being crosswise of the pipe. These openings were spaced about 3 ft. apart in the pipe and closed by suitable sliding plates of No. 8 sheet steel which work in grooved castings which bolt over the openings in the pipe. When one or more of these slides were opened the sand issuing from them was of the consistency of

mortar and built up very steeply. It was possible with a little care in operation to build up the sand to a 1 to 1 slope on the outside of the fill. If the slope was too steep the slides were opened wider and some water allowed to escape which flattened down the slope to any extent desired. The end of the discharge pipe was continued some distance away so that the water therefrom would not interfere with the levee building.

In making the levees in this manner advantage was taken of the fact that the heavy sand in long pipe lines is not carried in suspension by the water, but moves along the bottom of the pipe, three or four inches deep, and at a much slower velocity than the water. The action is very much like waves, there being alternately high and low places, the higher material being continually removed and carried forward to a depression. This peculiar wave-like action of sand transported in water is dealt with in many U. S. Government Engineer reports and in Johnson's "Surveying."

Sand Core Levees in California. In *Engineering and Contracting*, Apr. 29, 1914, R. G. Clifford describes the construction of a sand core levee in the Sacramento Valley, California, as follows:

Economical construction of these extensive levees necessitates the use of the materials immediately at hand and these consist of a deep sand in the river bottom and stratified sedimentary deposits of clayey silt along the banks. The average height of this 17.7 miles of river levee is 15 ft. and approximately 4,500,000 cu. yd. of material were necessary to construct a bank of sufficient stability to be absolutely safe under conditions of maximum flood.

Most of the recent levee work has been done with large clamshell dredges having 5 or 6 cu. yd. buckets, which pile the river sand up along the banks after clearing the timber and brush from the site. These sand banks are very slow in accumulating any growth and are thus left unprotected from scour and wave wash unless brush or tule mats are provided at considerable expense. A heavy growth of cotton wood, willow and black oak lines the river throughout its length and it was to take advantage of this natural protection to current and wave action that first suggested the use of a levee built with a suction dredge.

The levee was located with its center line 150 ft. back from the natural river bank except where the distance was less than 800 ft. to the existing levees across the river when this minimum flood plane width was used.

Retaining dikes, Fig. 13, are thrown up first by drag line excavators mounted on trucks having 16 wheels running on two standard gage parallel tracks. The booms are 100 ft. in length, and 3½ and 4½ yd. Bucyrus and Page buckets are employed in the varying material encountered. These drag lines backed down

the cleared right of way, digging a deep cut-off trench of sufficient size to furnish material for the two retaining dikes on each toe of the finished levee. The crown of these dikes was kept about 6 ft. below the finished top of the levee and was made 5 ft. wide with a natural slope of about 1½ to 1. The total yardage in-

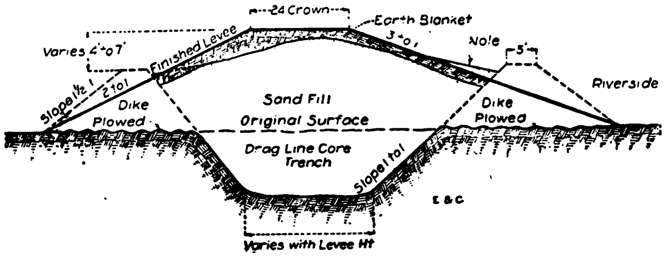

Fig. 13. Cross-Section of Sand Core Levee Showing Sequence of Construction Operations.

cluded in this drag line work for the river levee is 1,224,400 cu. yd. The operation of Drag Line No. 2, which did 60% of the work, is given in Table I.

The cost of excavating this 743,056 cu. yd. of core trench material and placing it in the two dikes is divided as follows:

Labor of operation	$24,013
Fuel, 8,645 bbl. oil	8,645
Superintendence and engineering	2,800
Moving and erection at beginning	2,400
Repairs	11,900
Total	$49,798
20% annual depreciation on $28,717 worth of equipment	5,743
Grand total (12 mo.)	$55,541
Cost per cu. yd.	$0.075

The efficiency of operation increased very materially after the crews became trained to handle this particular character of construction.

TABLE I.—OPERATION OF DRAGLINE EXCAVATOR (12 MOS.)

Operating, hr.	6,884
Digging, hr.	5,507
Per cent. of time digging	80
Yardage moved	743,056
Cu. yd. per hr. digging	135
Cu. yd. per bbl. fuel oil	87
Cu. yd. per lin. ft.	13

The best month's work was in Jan., 1913, when 120,128 cu. yd. were excavated in 744 operating hr. or 627 digging hr.

The dredge had a hull 150 x 35 x 9 ft. in size, and a 20-in. pump driven by a 650-hp. triple expansion steam engine. Crude oil costing 85 ct. per bbl. was used for fuel. The limits of digging were 7 ft. minimum and 36 ft. maximum, although the average was 18 to 32 ft. The lift was from 20 to 30 ft. with 1,400 ft. average length of pipe used. The crew consisted of 3 levermen, 3 enginemen, 2 firemen, 2 deck hands, all on the dredge, beside a shore gang of 34 men total for the two 12-hr. shifts. The levermen worked 6 hr. on and 12 hr. off, making an average of 8 hr. per day.

The dredge worked downstream so as not to require outside motive power for moving. The pipe was extended across the space between the river and levee center, and the distributing "pocket pipe" was supported on bents for an average distance of 700 ft. on a slight down grade along the center of the levee. Temporary wooden baffles kept the stream at the discharge end toward the center of the levee to prevent washing of the side dikes. The pockets are merely openings in the bottom of the pipe, opened or closed as desired by means of simple sliding gates operated by the attendant. The sand drains itself readily and builds up on slopes of from 1 on 10 to 1 on 4, depending on the fineness of the sand and the amount of silt present. The operation of the suction dredge for the 2,053,509 cu. yd. handled to date is given in Table II.

The cost of placing this 2,053,509 cu. yd. of sand core is divided as follows:

Labor of operation	$ 53,054
Fuel, 20,436 lb.	20,436
Superintendence and engineering	7,117
Repairs	27,727
Total	$108,334
20% yearly depreciation on $105,300, cost of outfit....	28,100
Grand total (16 mo.)	$136,434
Cost per cu. yd.	$0.067

Since there were 13 cu. yd. per lineal ft. of drag line work against 35 cu. yd. of suction dredge work, the average cost of each cubic yard of levee untrimmed would be $0.07, including the assumed 20% depreciation charge on equipment. This cost included the plowing of furrows parallel to the core trench underneath the side dikes to further prevent percolation between the original ground surface and the levee.

To compare with a levee built by a clam shell dredge, the side slopes being the same but with no core trench excavated, the cost of the 13 cu. yd. of dragline work would have to be added to the

cost of the suction dredge yardage and the unit price would be $0.094 instead of $0.07.

The justification for this additional expenditure is found in the efficacy of the earth blanket on the levee for furnishing a ready foothold for shrub and grass growth and the advantage of the core trench in breaking up the line of percolation and doing away with danger of the levee sliding on its base. It is also evident that to take advantage of the protection afforded by the natural growth along the river it was necessary to use the hydraulic fill type of levee, which in turn necessitated the use of the dikes. The presence of the sand in the core is the only certain way of preventing dangerous burrowing by gophers and other small animals.

In addition to the above levee cost there is a charge for pulling up the sediment in the dikes so as to cover the levee faces, as shown in Fig. 13. This covering sods readily and is soon comparatively water tight, while the growth starting on it without delay aids greatly against wave wash. Little of this trimming has yet been done, but so far has cost about $3,000 per mile, or about $0.012 per cu. yd. of material in the levee, the work being done by teams. Since a road 24 ft. wide was to be built on the top of this levee, most of this trimming cost would apply to any form of levee constructed.

TABLE II.—OPERATION OF HYDRAULIC DREDGE (10 MO.)

Operating, hr.	10,730
Pumping time, hr.	6,362
Per cent. of time pumping	59
Yardage moved	2,053,509
Cu. yd. per hr. pumping	323
Cu. yd. per lin. ft.	35
Cu. yd. per bbl. fuel oil	100

Bibliography. "Relief from Floods," John W. Alvord and Charles B. Burdick; "The Improvement of Rivers," B. F. Thomas and D. A. Watt.

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CHAPTER XXII

SLIPS AND SLIDES

General Discussion. An English author, John Newman, has written a book on the subject of "Earthwork Slips and Subsidences Upon Public Works." He cites some fifty "causes" for slides in cuts and embankments, but nearly all of them are merely varieties of one cause, namely the saturation of earth with water.

The term "slip" is perhaps preferably applied to relatively small movements of earth; and the term "slide," to relatively large movements, such as "land slides."

Increasing the unit pressure on earth often increases the coefficient of friction. Whether this is universally true, is yet to be shown. But if it is universal, increasing the load on earth will increase the angle of repose. More tests on the coefficient of friction of different earths under varying unit pressures are badly needed. Lubricating earth with water decreases the coefficient of friction and reduces the angle of repose.

The jarring of passing trains reduces the coefficient of sliding friction of earth upon earth and is the cause of some slips.

High embankments built upon side hills in a clayey country often cause extensive slides of the underlying earth, and settlements of the embankment. Where experience has shown that such slides are to be expected, tile drains may be used to advantage in the site of the proposed embankment.

Often there is no way of predicting a slide, and when it begins it is too late to do any draining of the subsoil. The fill has then to be carried up until the slipping stops of its own accord. An engineer may find upon examination that the real source of trouble lies in the damming back of water by the new embankment, which water by soaking into the subsoil so reduces the coefficient of sliding friction as to cause the slip. In that case the remedy is obviously drainage ditches along the upper toe of the embankment, leading to a culvert.

It would be a waste of words to attempt to outline all possible methods of getting rid of water. In many cases it is impossible, with reasonable expense, or even with unreasonable expense, to get rid of the water that saturates and lubricates the subsoil.

If embankments are to be built upon soft swampy muck, a compression of that muck is inevitable. The engineer should endeavor to secure a uniform distribution of the earth load so as to secure uniform settlement. This uniform loading he should have *during* construction as well as afterward. That is he should build the embankment up in horizontal layers — not by end dumping — if he can; for a concentrated load will simply push the

muck out from under the load and not compress it. If it is impracticable to build up in uniform layers, then it may pay to build a log or brush mattress upon which to dump the earth. The author has read very many accounts of the building of such mattresses written by those who seemed to think that in some way the mattress served to buoy up or float the finished embankment. As a matter of fact these mattresses ordinarily serve but one useful purpose. They secure an even distribution of the earth load during the construction of the embankment, and so prevent the soft muck from being pushed out from beneath the embankment. In very bad cases a close line of sheet piling along each toe of a proposed embankment may be used instead of the mattress, for it must be remembered that the lateral escape of the subsoil muck is what is to be prevented if possible.

It is obvious from the preceding discussion that in building an embankment the engineer should avoid dumping a mass of marl or soft clay in such a way that subsequent water saturation of it will cause a slip. Many marls are wholly unfit to form an embankment, and if a pocket of such marl is encountered in excavation it should be wasted.

Clay, as is well known, shrinks some 5% when thoroughly sun dried, thus opening cracks or crevices through which water may gain access to the material below. A sod covering or a foot or so of sand covering over clay that becomes treacherous in this way will keep it from drying out.

The Cause and Cure of Slides. George L. Dillman in a discussion of a paper by D. D. Clarke, *Trans. Am. Soc. C. E.*, Dec., 1918, gives the following:

Water lubricates and lessens friction. Water accumulates a head, and forces itself into and through otherwise impermeable material, thus extending the lubrication; but the greatest effect of water is from its pressure. It acts like millions of jackscrews, under and back of the slide, to produce motion. The film of water back of and under the slide has only to be thick enough to be continuous in order to transmit the pressure of its whole head in this manner.

We have articles on the pressure of water under dams. A slide is a dam, in all essential features, until motion begins. Then, fortunately, the continuity of the water film is broken. At the instant the continuity is sufficiently broken, motion ceases. Then, if conditions are right, the inflow of water increases the continuity of the film, flows into the cracks, and motion again begins.

A slide is frequently a number of dams, according to different planes of motion, any one of which may move. It matters not

how saturated is the mass above the bottom of the slide, the analysis of bottom pressures and effects is not changed thereby. Although slides of some extent offer at first varying evidence, crumpling at the toe, upheaval in places, subsidence at the head, and lateral motion in varying degrees, they can all be traced to one phenomenon by proper analysis. There is frequently a swampy place at the head, sometimes attaining the dignity of a lake. There are usually springs at the toe, frequently also along its trace on the surface. These may develop by erosion into gulches which hide the cracks, the crumpling, and other evidences of motion.

There is no need to enlarge on the cause of slides. Every fact in evidence can be traced directly to water, principally to its pressure.

Sometimes, the surface can be drained sufficiently to effect a cure. Surface drainage will always help; but surface drainage is often difficult, especially after motion has developed a cracked wart-like surface, as this tends to hold rainfall and guide it to the surface of motion, or several surfaces of motion.

Sub-drainage, which will kill the water pressure, is infallible. There never has been a slide that could not be cured in this way. There are cases where the expense is not warranted. There are cases where the whole slide can be sluiced away. There are also cases where the motion is so slow, or its effect so small, that the removal of the material as it comes, or not removing it at all, is the best answer. Incidentally, removal is drainage.

Subsidence at the head of the slide tends to the formation of swamps and lakes, which, in turn, supply the water to fill the cracks, to form the pressure, to produce motion, to make more subsidence, and so on in a never-ending cycle. The interruption of this cycle is most certainly accomplished by killing the head of water acting on the surface of motion. Draining the swamps and lakes will help. At Panama one enthusiast proposed concreting the whole surface of the slide to prevent the ingress of water. This might do, if there were not probably some subterranean supply of water, possibly with a great head, that would not keep out. Such construction might be an actual hindrance, instead of a help, and might serve to hold the water and increase, instead of decrease, the head.

In some cases increasing the resistance to motion has been tried, by masonry and wooden bulkheads. These have been effective where it only needed another "straw," but have generally been disastrous. Drainage by perforating the bulkhead is taught as a rudiment in retaining walls.

Far apart as they may seem, there is much similarity in

slides, retaining walls, and dams. The analysis is nearly identical, gravity, friction, and hydrostatic pressure. Sub-drainage will cure the slide, is necessary to the stability of the wall, and increases the safety of the dam.

[In the author's opinion, Mr. Dillman is wrong in attributing slides mainly to water pressure. Water in clayey earth decreases the coefficient of friction, so that sliding may occur without any change in pressure.]

A Landslide at Mount Vernon. N. H. Darton, in *Engineering News*, Feb. 25, 1915, gives the following: Mount Vernon is situated on a bluff about 100 ft. high, fronting on the Potomac River. In Washington's time extensive land slides occurred on the front of the bluff, and a few years ago evidence was discovered that another slide was beginning. The movement was extending so far as to threaten the broad lawn in front of the

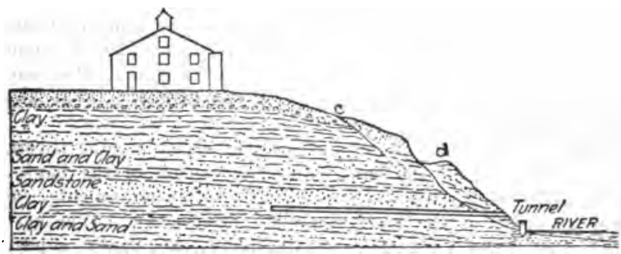


Fig. 1. Section Through Mount Vernon Bluff

mansion itself. A small drainage tunnel was started in the bottom of the sandstone stratum and was driven back from the river front a distance of some 200 ft. From this drainage tunnel a considerable flow of water at once started and continued for several months. At the end of that time the flow gradually diminished and now remains of moderate amount but practically constant. The draining of the overlying strata has apparently been so thorough that they are now able to sustain the load upon them without further movement. A masonry wall along the river at the water's edge prevents further undercutting by the waves.

An Extensive Earth Slip near Hudson, N. Y. *Engineering News*, Aug. 12, 1915, gives the following: The slip affected an area of 15 acres belonging to the Knickerbocker Portland Cement Co., on Claverack Creek. The first visible incident in the disturbance was the movement of a section of earth 50 ft. wide by at least 30 ft. deep and 200 ft. long, about 200 ft.

southeast of the power house, and this section toppled over into the creek flowing 120 ft. east of the power house. This slide was followed immediately by others in ever-lengthening arcs, until a huge storage pile of crushed traprock was undermined. The pile then sank 20 to 25 ft. over its area (160 ft. in diameter). This sinking caused the settlement and destruction of the coal trestle and power house, in the order mentioned.

The disturbance extends over 15 acres of ground. The creek was pushed from 40 to 200 ft. out of its original course and its channel was dammed so that a new channel had to be blasted almost immediately to prevent the flooding of the plant. The water in the Claverack is from 6 to 8 ft. in depth. The entire earth movement was over in 2½ min. The total damage will probably reach $250,000.

The buildings of the company were on flat footings with no piling. The soil is the blue clay common to the Hudson Valley. The general slope is toward Claverack Creek (30 ft. wide) which bounds the company's property on the east, the water level being about 15 ft. below that of the property. The slope is about 1 on 2.

The nature of the slippage indicates that water seeping through cracks at the foot of the bank caused a section of the bank to cave in, and this started a succession of similar movements, each farther away from the creek than its predecessor. Whether a lateral flowing of the clay subsoil under the heavy superincumbent load had anything to do with the caving cannot be determined.

Land Slides at Bulls Bridge Hydro-electric Plant. Charles R. Harte, in *Engineering Record,* May 27, 1916, gives the following: Water passing through the power house is carried through a long canal from the reservoir to the forebay. This canal follows a hillside, the easterly side in cut and the westerly side in fill. Slides developed in the hill side that threatened to fill and destroy the canal. In 1907 an area about 100 ft. wide, extending 200 ft. up the hill, pulled forward several feet in as many hours, opening, at the top, a crack 3 or 4 in. wide, while the surface dropped nearly a foot.

The entire affected area showed cracks parallel to the canal, far apart at the top but closer together toward the lower end, where the ground looked like a plowed field, and was 2 or 3 ft. above its original level. At the face the top overhung the base, and continually dropped down masses of a cubic yard or so. Under the direction of E. H. McHenry, then engineering vice-president of the properties, the slide was attacked from the

front. The material, a hardpan with streaks of greasy clay of various colors, was so saturated that when touched it "melted" and flowed, but in a very short time the face was sufficiently drained to act as an abutment. The ditches were then pushed to the end of the movement, which had apparently extended 10 or 12 ft. below the surface, and no further trouble was experienced.

Four years later an area of 7 acres immediately south of the first slide dropped about 4 ft. vertically, and moved forward, opening up a main crack about a foot wide and 30 ft. deep at the upper edge, 300 ft. from the canal. A series of smaller cracks appeared between, while the base, some 20 to 40 ft. high at the point, became saturated, bulged outward and dropped considerable material on the berm, which was between it and the water.

Following the same general plan as in the case of the first slide, the face was "bled" by a series of ditches driven into it, a cut-off ditch was dug outside the limits of the movement to trap off all surface water, and, at the point of maximum disturbance, an exploration shaft was sunk some 25 ft., where a sliding plane of 3 ft. of clay was found. On this a drift was pushed 25 ft. up the hill to rock and 100 ft. down the hill to the base of the canal bank.

A second drift was started at the bank face, 100 ft. north of the first, and a little above the canal level. This was driven in a northwesterly direction 80 ft. to the rock, and had a rising grade from the bank of about 2%. Thirty feet from the mouth a lateral was run nearly to the exploration shaft, and from near the end of the main drift another lateral was run northwesterly 240 ft., with two short branches eastward to rock.

Comparatively little water was intercepted, but the behavior of the slide indicated that the small quantity found was the cause of the trouble. Apparently it had accumulated along the rock until the head was sufficient to start the mass, but this movement largely increased the size of the cavity, and some little time elapsed before the head was again sufficient to cause a succession of moves.

The drifts were timbered with local chestnut, at least 8 in. in diameter for the sets, and 3-in. plank for the sides and roof. A bulkhead was maintained at the face throughout, and frequently the work was stopped for a day or so to drain off an unusually wet section. The advances were made by driving the roof and the top side plank, removing the top board of the bulkhead, excavating to the ends of the roof and side boards just driven, and setting the top of the next bulkhead.

It was expected that the drifts would have to explore the entire line of the break, and future developments may necessitate such a course, but so far it would appear that the work already done has been entirely successful in anchoring the area, although less than half has been explored. There is evidently a series of planes of sliding, but, between the surface drains and the drifts, enough water has been intercepted to protect the planes below.

Preventing Slides on the Chicago Canal. In a report of the engineers of the Chicago Drainage District, quoted in *Engineering and Contracting*, May 27, 1914, slides developing on the side of the Calumet-Sag Channel are discussed.

Three types of sliding ground have been encountered as follows: (1) Structural breaks resulting from inability of a layer of drift to hold the weight of the overhead bank. (2) Normal or gravity slides. (3) Surface erosion.

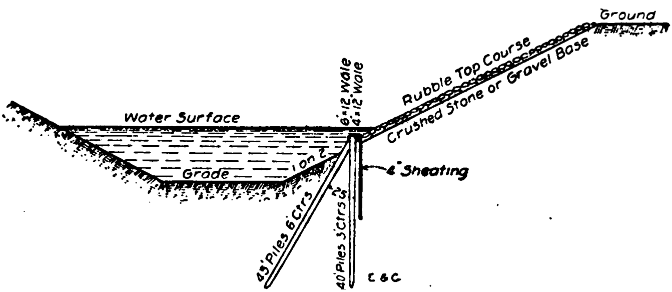


Fig. 2. Slope Paving, North Shore Channel, Chicago Drainage Canal.

Structural breaks occur at points where a layer of shale upon exposure to the atmosphere disintegrates and crumbles. A crack or fissure then develops in the bank, sometimes at a distance of 200 to 300 ft. from the channel center line and this crack gradually widens and deepens as the bank moves slowly into the channel. Instead of a layer of shale, the prime cause may be a peat stratum, or it may be a soft, silty or unstable clay.

The normal or gravity slide results from the movement of the overhead bank upon a slippery layer of clay or other material, the line of stratification of which is clearly defined. It is due almost entirely to an excavated slope steeper than the angle of repose of the particular formation then being excavated, and in many cases has been further aggravated by the superimposing on the berm

heavy spoil banks at a comparatively small distance from the slope.

Surface erosion is a gradual sloughing of the surface of the slopes due to the weathering action of the elements. In addition to rain and wave action, the action of frost is a contributing cause of slides of this character. The freezing and thawing of the bank tends further to aggravate the sloughing of the surface of the slopes, so that the sowing of shallow rooted grasses and like vegetation is not in all cases a sufficient preventive means.

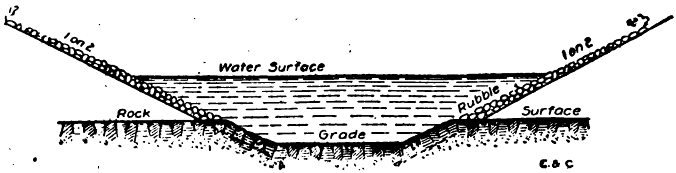


Fig. 3. Slope Paving Calumet Sag Branch Chicago Drainage Canal.

Rip-rap on a 12-in. layer of crushed stone or gravel is used with success to prevent surface erosion and even slides but at times has to be held in place with piles. Where rip-rap paving can be placed before water is turned into the channel it is better to carry the slope paving to a solid foundation.

The Great Slides at Panama Canal. According to General Goethals these slides were of two kinds. One is the ship-launching type, where a natural slip-plane exists on which the superincumbent mass begins to slide under critical conditions of lubrication. This is slow moving and may be very large and exert enormous pressure down hill. The Cucaracha slide was of this type. The other class of slip is the plastic flow kind, where a clay-like soil becomes suddenly plastic or semi-liquid under certain conditions of moisture and pressure. The Culebra slides were of the plastic flow type.

The magnitude of the slides at Panama precluded the possibility of stopping them with piles. Drainage would have been very costly, and, due to the excessive rain fall, possibly not effective. Nothing could be done but remove the sliding material as it reached the canal prism. This has been done, and now that all the sliding ground has been removed the remaining banks appear to be stable. The volume of these slides was enormous having reached about 50,000,000 cu. yd. by Dec. 30, 1915. These

unexpected slides added greatly to the estimated cost of the canal.

A Remarkable Landslide at Portland, Oregon. D. D. Clarke, in two papers before the Am. Soc. C. E., *Trans. Am. Soc. C. E.*, Vols. LIII and LXXXII, discusses the treatment of this slide.

During 1894 two small reservoirs were constructed for the city of Portland. During their construction a slight movement of adjacent land was noticed. This movement increased in size so as to affect the reservoirs as soon as they were first filled. The reservoirs were immediately emptied and were out of use for ten years.

Small shafts (22) and wash borings (33) were used to study the movement of the slide for a period of years. The dimensions of the moving ground were at length determined to be approximately 1,700 ft. from east to west, and 1,100 ft. from north to south along the reservoir front — an area of approximately 29¼ acres — the depth ranging from 46 to 112 ft., the average being 77.8 ft. The approximate volume was 3,400,000 cu. yd., and the approximate weight 4,600,000 tons.

The borings and open shafts revealed the presence of a thin seam of blue clay along the surface of the bed-rock, with numerous water pockets in immediate connection therewith, several of the underground water pockets having considerable volume. Two of the largest of these water pockets were drained with pumps (the total pumpage aggregating several million gallons) with a marked deterrent effect on the movement of the slide, as indicated by the periodical instrumental surveys.

Comparisons of Weather Bureau records of precipitation with the monthly movement of the slide indicated a close relationship between the two — if it did not offer absolute proof that the rate of movement of the slide depended on the volume of the rainfall during any series of months.

After a study of all the observed conditions it became evident that the required remedy was drainage. Accordingly a total of 2,507 lin. ft. of drainage tunnels, with timber supports, was constructed between June, 1900, and December, 1901, at a total cost of $14,161, or an average cost of $5.65 per lin. ft. for materials and labor.

The results secured by the construction of these drains were considered very satisfactory, and for a time it appeared as if the slide problem had been fully solved.

The volume of drainage from the tunnels was carefully observed for the 2 years following their completion, and was found to range from 10,000 to 15,000 gal. per day in summer, and from 25,000 to 75,000 gal. per day in winter; and at the end of 2 years it was

decided that the drains were doing effective work and that it would be safe to proceed at once with the work of reservoir repairs.

During March, 1904, immediately following the adoption of a plan for tunnel and reservoir repairs, it was noted that there had been an accelerated movement of the slide. There had been unusual rainfall during the preceding 4 months, amounting to 27% more than the average for the same period during the past 21 years. To remedy this, the construction of supplemental drain tunnels was started early in 1904 and finished in 1906.

In constructing tunnels the excavated material was hauled from the heading to the nearest shaft in narrow gage cars, which were then hoisted to the surface and dumped. Only a small force was employed on this work, one or two crews at different points, sometimes with two shifts per day, each crew consisting of: One tunnel man, at $3.00 per 10-hr. day; two helpers and one or two top men at $2.25 per 10-hr. day, each; and one hoisting engineman.

The timber supports were framed by a man especially detailed for that work.

A total of 4,021 lin. ft. of new tunnel was built between April, 1904, and August, 1906, at a total cost of $26,896, exclusive of engineering and superintendence, or an average of $6.69 per lin. ft., as compared with $5.65 per lin: ft. for work of a similar character completed in 1900–01. This increase in cost was due largely to the advance in the prices of material and labor during the intervening period. In 1901 outside laborers were paid $2.00 per day of 10 hr., and tunnel men $2.25 and $3.00 per day; and timber cost $8.50 per 1,000 ft. b. m., delivered. In 1904 and 1905 the same rate per diem was paid for labor, but the working hours were reduced from 10 to 8. This is equivalent to an advance of 25% in the cost of labor; at the same time an equal or greater advance had taken place in the price of timber and other construction materials.

The 4,021 ft. of new tunnels added to the length originally constructed gives 6,528 lin. ft. in the complete drainage system.

The material encountered in the tunnel extension work was chiefly yellow clay, intermixed with fragments of basalt. No large pockets of water were discovered, and in that respect the work did not accomplish all that was anticipated, but the aggregate volume of drainage from all the branches has been large, ranging from 18,000 to 108,000 gal. per day during some years, the quantity depending on the season of the year and the attendant rainfall. During recent years the volume of this drainage has been somewhat less than noted above.

Concrete Tunnel Culvert. It was realized that the timber supports would soon decay. A study was made to determine the best method of lining the drains so as to insure permanency.

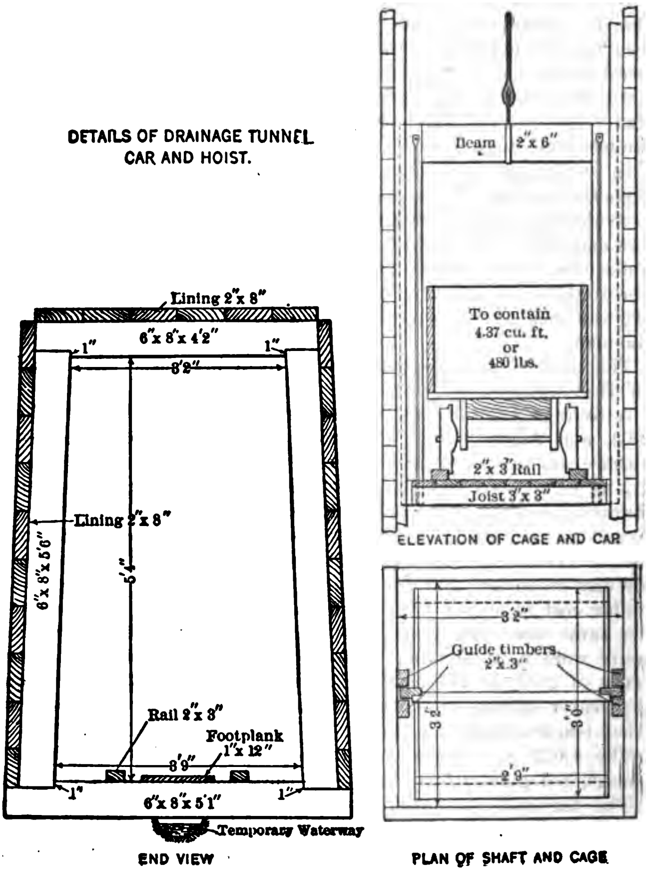
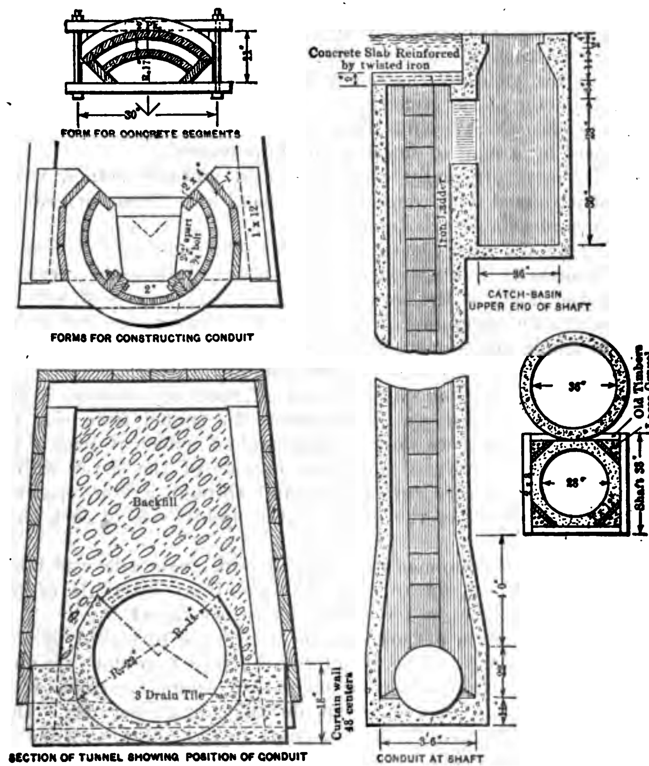


Fig. 4. Timbering Details, Portland Drainage Tunnels.

The scheme adopted was well suited to this class of work. A circular concrete conduit was built in the tunnels, the base and sides of which were constructed as a monolith of the dimensions shown in Fig. 5.

The advantages of this method of construction were two fold: First the distance between the side walls permitted a man to move freely and push a car with a narrow body. All construction



PLAN ADOPTED FOR CONCRETE CONDUIT
IN DRAINAGE TUNNELS UNDER SLIDING LAND
TRACT WEST OF CITY PARK RESERVOIRS
(1904)

Fig. 5. Plan Adopted for Concrete Conduit in Drainage Tunnels Under Portland Landslide

materials were transported from the foot of the nearest shaft in cars running on a narrow gage track laid on the tunnel sills, or on the sewer invert after it had been built. The material for

back filling behind the side-walls and over the top of the sewer was hauled in the same manner.

Second, this style of construction made it possible to cast the arch blocks a sufficient time in advance to permit them to become thoroughly seasoned before being put in place, and consequently the work of back filling was not delayed while waiting for the setting of the arch and the removal of its supports.

The diameter of the conduit was fixed at 28 in., that being the minimum size which would admit of comfortable inspection from end to end by a man of small or medium stature.

Of 22 shafts originally excavated, 7 at suitable points, were permanently lined with concrete; the others were filled with earth on the completion of the tunnel work.

In placing the arch blocks in position, the ends were cemented to the side-walls, but no attempt was made to close the crevices between the blocks at the crown of the arch. This space of, say, ¼ in. in width for every foot in length of the conduit, was left open so as to admit any seepage water which might percolate into the tunnel and thence to the top of the conduit.

At intervals of about 50 ft. a cut-off wall of concrete, 6 in. thick and 18 in. high, was built across the tunnel from side to side. These walls were deep enough and of sufficient length to cut off any flow of water along the outside of the sewer walls. The water is conducted into the conduit through a 3-in. opening left near the bottom of the invert at the up-hill side of each cut-off wall.

At each side of the conduit a line of 3-in. drain tile was laid, connecting with the opening in the conduit at intervals of 50 ft., this opening being a few inches above the invert.

The concrete materials used in the work were furnished by the contractor. Mixing and laying of the concrete were done by day labor under the Department foreman. The tunnel foremen were paid $3.00 per day, and other inside labor $2.25 per day. Detailed cost kept during the period from June 1, 1904, to June 1, 1905, showed that 2,746 lin. ft. were completed at an average cost of $3.20 per lin. ft. for the materials and labor of constructing the conduit and back filling the tunnel.

Treatment of Railway Slides. An abstract of a report by the Roadway Committee of the American Railway Engineering and Maintenance-of-Way Association was published in *Engineering News*, Dec. 10, 1908, from which the following is taken:

Slides on railroad right-of-way may be classified as follows: (1) Slips of material on the sides of the embankment away from the road bed; (2) slips of portions of the cut toward the road bed; (3) general slides of the land.

Slides of embankments are endless in variety and magnitude. They always occur in wet weather. The earth becomes surcharged with water, which increases its weight and at the same time lessens its cohesion. The slide starts on a plane of rupture that is usually curved.

The cure of slides in most cases is surface and subterranean drainage, which is often difficult and costly.

The driving of piles in both embankment and excavation to hold masses of earth is often resorted to. This is never more than a temporary expedient, and is advisable only in special cases.

Retaining walls at the foot of a slope may sometimes be necessary where right of way is restricted. But in the open country in nearly all cases where the ground can be obtained, the flattening of the slope is the most economical, the most efficient and permanent method of treatment. The lobe at lower end of a slide often gives a good point of support or foothold for the filling used in restoring the roadbed.

In embankment slides, the roadbed can be restored after it is dried out in a measure, by filling in with suitable material. Usually the steam shovel will be the best method to use.

The way to get rid of slides in cuts, is to take them out by the cheapest and speediest way possible. Only in rare instances are other methods effective.

Piling a Sliding Railway Cut. *Engineering News,* Apr. 30, 1918, gives the following: The railroad has at the point in question a double track on a curve of 2½° (with 7 in. elevation) at the foot of a cut about 40 ft. deep in sloping or sidehill ground. The material is a wet yellow clay, and lies on a stratum of shale or hardpan. Water soaking through the clay mass gives a smooth and slippery or lubricated surface to the shale, and upon this the clay slides. Near the top of the cut is a public highway known as the Homestead Road. In January, 1906, considerable trouble was experienced, and a number of teams were employed to keep the road passable by filling in from the top the earth that was settling away towards the cut.

In the spring, two rows of piles were driven along the lower side of the original line of the road and two rows of piles were also driven at the toe of the slope. The rows were 4 ft. apart, and the piles also 4 ft. apart, the rows being staggered. The piles were driven with a 2,800-lb. hammer, and were driven as far as possible into the substratum of shale, the penetration being generally about 6 ft. A layer of brush was filled between the two upper rows of piles, and this was covered with earth to a level about 2 ft. below that of the road. The road was then backfilled to the original line and covered with broken stone. No

brush filling or other work was done at the lower row of piles. There are over 900 piles in these rows. Two French drains about 3 ft. wide were then built up the slope, being excavated into the shale and filled with about 4 ft. of loose rock. These were very expensive. There has been no apparent movement of either of the double rows of piling, or of the slide, since this work was done, and the work seems to have accomplished its purpose.

Preventing Slips on Railways. *Engineering News*, Mar. 16, 1916, comments upon the success attained by the Missouri, Kansas and Texas Ry. in maintaining uninterrupted service in the Mississippi Valley during periods of record floods. A summary of the chief engineer's instructions for slip prevention is given.

A common cause of slips in embankment is illustrated in 1, Fig. 6, where the fill has been widened without properly stepping the old slopes. This new fill of impervious material is often placed in such a way that the shoulders of the fill are higher than the old subgrade, forming pockets or troughs that retain water and cause soft spots in the track. Care should be taken to prevent this by removing the ballast from eroded or settled parts of roadbed and bringing the roadbed to grade with new material. The slopes of the old fill should be plowed before adding new material.

The same precautions apply to roadbeds widened for additional tracks and to widening roadbeds in fills. Two examples of the effects of faulty drainage in widened clay embankments are shown in 2 and 3, Fig. 6. Transverse stone-filled trenches would have prevented these slips.

In cuts, when a soft spot does not extend to a great depth and the cut is shallow, it is economical to widen the cut, lower the side ditch to a depth below the lowest pocket and drain the roadbed into the ditch by means of a stone-filled trench or a tile drain (see 4).

When soft spots have extended too deep to be economically drained by deepening the surface ditches, they should be drained by tiling laid parallel to the track and below the lowest part of the soft spot (see 5 and 6).

In a cut where there is seepage from both sides, intercepting drains should be constructed on both sides of the track (7); but if the seepage is from one side only, a single drain should be on that side.

Where there is probability of water from a wet cut entering an adjoining embankment, a tile drain or a stone-filled trench should be constructed across the roadbed near the end of the cut, to intercept the flow (8).

9 and 10 represent typical conditions of pocket formation in

cuts and show the way drains should be laid to take care of such formations.

11 gives in detail the method of laying and back filling tile

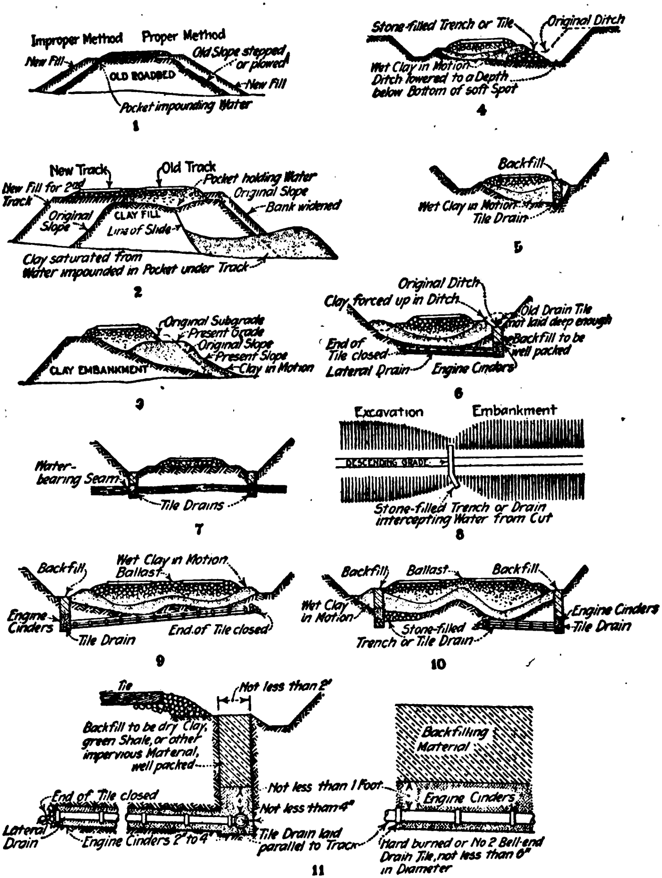


Fig. 6. Subdraining Roadbed to Prevent Slips.

drains in cuts. Notice that these drains are for subsurface water and are not intended to take the place of the side ditches.

Some general points to be borne in mind follow: Determine

the depth of water in the pockets by digging a hole. Subdrains must always be laid below wet clay or below the lowest point in the pockets. If they are not so laid, they will not drain the pocket and will soon be displaced by slips. Trenches should be made as narrow as possible and should be braced during construction, if necessary. Drains parallel to the track should be laid as close to the track as the stability of the soil will permit and according to their depth, but they should never be nearer to the ends of the ties than 2 ft. The drains should have a fall of not less than 4 in. per 100 ft. In deep trenches and in soft or slipping material only bell-end tile should be used, because it retains its alignment better. The tile should be hard-burned and should never be less than 6-in. in size.

After the trenches have been excavated to grade, about 3 in. of cinders should be placed in the bottom to keep out the wet clay. The tile should be laid on the side of the trench farthest from the track, but not less than 4 in. from the side of the trench. The sections of tile should be laid from the low end of the grade or outlet upgrade, the bell ends upgrade. Joints should be left open enough to permit water to enter, but not so open that dirt can enter. The upper end should be closed with a block of wood or slab of stone, and the outlet should be covered with wire netting to prevent animals from getting in.

The backfill should be made of cinders all around and to 12 in. above the pipe. The joints may be lightly covered with hay or straw while the backfill is being made, to keep the joints open. The fill directly over the cinders should be selected material and should be carefully tamped to insure stability of the roadbed. The tile drain is not intended to take care of surface drainage, the ditches providing for this.

If all pockets are not tapped and drained by drains parallel to the tracks, lateral drains should be laid at such intervals as may be necessary. Vegetation with deep roots must never be allowed to grow up over the subdrains.

Drainage Tunnel to Stop Sliding Clay. H. G. Wray, in *Engineering Record*, July 29, 1916, describes difficulties encountered in shifting the Pennsylvania Railroad tracks at Cincinnati, Ohio. In eliminating a grade crossing it became necessary to shift the tracks into a hillside. Several test pits dug into the hillside disclosed a peculiar formation. The entire hill consisted of a soft clayey material resting on a layer of stratified clay mixed with limestone, which dipped at a very abrupt angle toward the river. See Fig. 7.

At the first cut of the steam shovel, in preparing the new

subgrade for the railway tracks, serious cracks developed in the hillside, endangering a block of houses.

A concrete retaining wall was planned to replace an existing stone wall. Meanwhile the foundations of 10 or 15 houses began to give evidence of the sliding action of the hillside, as large cracks began to appear in them, damaging the property to a considerable extent. In view of these houses being damaged when the construction had barely begun, it was decided to buy the property and omit the construction of the retaining wall.

During the rainy season of the next year following the pur-

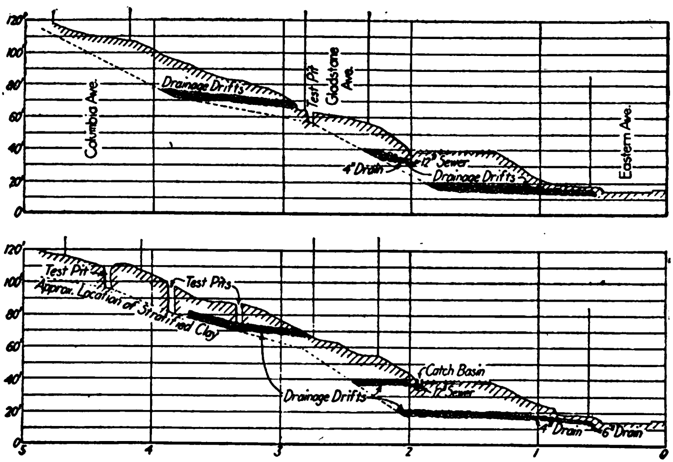


Fig. 7. Drainage Drifts Used to Stop Sliding Clay Hillside.

chase of this property the sliding action of the hillside increased and cracks developed in the surface of Columbia Avenue, making it necessary to take steps to protect the street. It was decided, therefore, to drain the hillside to see whether this would stop the sliding.

Drainage drifts were driven through the hillside at frequent intervals to provide outlets for the ground water and to eliminate, as far as possible, its spreading out over the surface of the substrata. These drifts were miniature tunnels 4 ft. high by 3 ft. wide. As the digging progressed each drift was sheeted at the top and sides with 2-in. oak plank. Two men working in each drift were able to drive between 2 and 4 lin. ft. of tunnel per day.

One man removed the material, while the other hauled it to the mouth of the tunnel by wheelbarrow.

After the completion of the drift it was backfilled with coarse rock in order to allow the ground water to flow through it.

These drifts were of varying length, owing to the character of the material encountered. They were, however, driven in each case until the underlying stratified clay was reached. Some of them are below the tracks and extend up into the hillside north of the tracks. Each drift was given an outlet to a sewer by a 4-in. drain-pipe connection. They were driven at an average cost of $5 per lin. ft. This scheme of underdrainage has materially relieved the situation, and it is believed that it will be a successful undertaking.

Two years after the work was started, and while the drainage drifts were under construction, a surface talus of 5-ft. depth started to erode and slide. It was decided more practical in this case, since the slide was of comparatively shallow depth, to build a retaining wall to hold the hillside in place.

The Treatment of a Wet Cut. *Railway Age Gazette,* May 17, 1912, gives an account of difficulties encountered at Neff's Cut, Pa. on the Penn. Ry. This cut is 2,900 ft. long, and is located on a summit. It passes through impervious potter's clay, which was depressed under the tracks by the heavy weight of passing trains and raised in the ditches, requiring the constant employment of a large force of men to keep the tracks in surface and line and the ditches open. The extra maintenance cost was about $900 per month.

Following surveys made in 1909 the grade was revised and the tracks raised 3 ft., 2 ft. of cinder ballast being used to prevent the muck from reaching the surface. On this was 1 ft. of trap rock ballast.

A 24-in. cast iron pipe under the tracks was lowered to a depth of about 6 ft. below the top of the rail, with a good fall and extended by the use of additional terra cotta pipe to an open ditch draining to the river. Manholes were provided in the pipe line for cleaning out sediment.

The northern intake of the drain was connected by a covered flume of pipe down the slope of the cut, which drains all the water carried by a berm ditch during periods of heavy rains. As the rainfall is very great it materially assists in keeping main drain well flushed. Where the main drain crosses the side ditches, concrete inlets were installed, also connected by 24-in. pipe on each side with the French drains, which were laid by hand in the side ditches.

Standard ditches and slopes were constructed on each side of

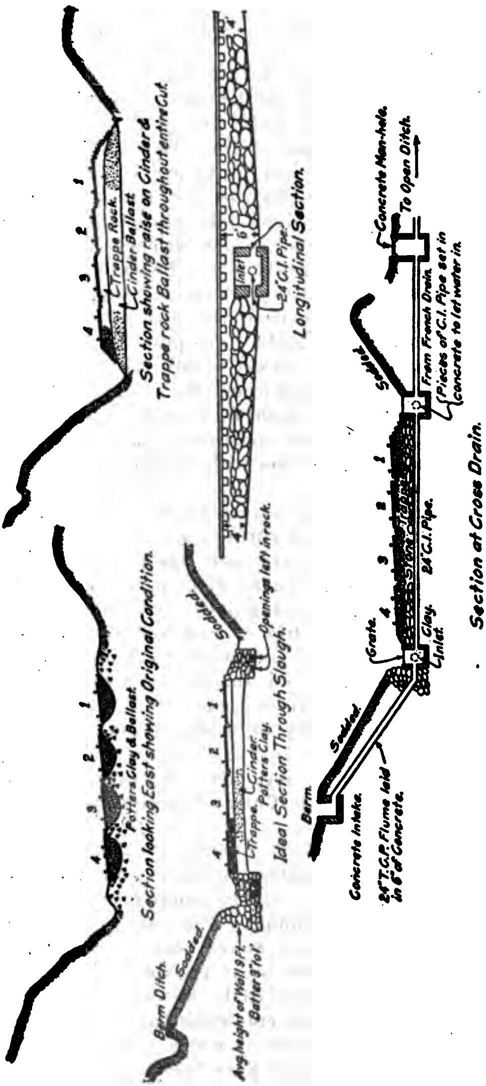


Fig. 8. Typical Sections Showing Methods Applied in Draining Neff's Cut.

the cut, the banks were sodded, and a curb of small stone set along the foot of the slope to prevent scouring which would allow the sod to slip.

On both sides of the track it was necessary to shore up and excavate through the slough, at the ends of the ties, to the depth of from 4 to 6 ft. and 6 ft. wide; the grade at the bottom running toward the main cross drain. These ditches were filled with large stone in such a way as to provide ample openings to allow the water to find its way to the main cross drain. The weight of the stone combined with its thrusts against the slopes prevents the raising of mud in the ditches. It is interesting to note that where the excavation was being made the men had to leave the ditches when trains were passing, as their weight forced the muck and water from the roadbed into the ditch in small streams, as if shot from a force pump.

On the north side of the railway a solid formation exists about half way through the cut, and where the strata of slate and shale end, a heavy retaining wall 2,100 ft. long was constructed to hold back the slopes, which had constantly slipped and filled the ditches. This wall in connection with a large French drain doubly insures against mud raising.

Since the completion of this work in August, 1911, it has been possible to maintain line and surface, a standard slope and ditch and to dispense with all extra men, thereby reducing the cost of maintenance of this section by $900 per month. In addition the annoyance of trains reporting daily "track bad in Neff's cut" has been eliminated. The life of rail and fastenings has been increased, as prior to this treatment the soft roadbed caused many broken splices, line and surface bent rails and the constant gaging lessened the life of ties.

On account of the density of traffic, carts were used to remove all excavation.

The cost of treatment lasting over two years was $16,577.

Large Slides in N. P. Ry. Cuts. *Engineering News*, Mar. 25, 1915, gives the following:

The Day Island cut on the N. P. Ry., 10¼ miles from Tacoma, Wash., gave unexpected trouble, as there were no surface indications to cause suspicion, and in smaller cuts very hard cemented material had been found. The cut was in ground sloping gradually back from Puget Sound, and was about 700 ft. long with a maximum depth of 50 ft. at the center line. About 200,000 cu. yd. of slide were removed by steam shovel in excavating a cut of 100,000 cu. yd. The cut broke back to a maximum distance of 360 ft. from the track at which point a depth of about 130 ft. was reached. It would have been necessary to remove a

larger yardage had not a pile bulkhead been built for a distance of 630 ft. The material in the cut was loam with some blue clay, and it carried a considerable amount of water.

The Tenino cut was estimated at 131,000 cu. yd., but there were removed before its completion 866,000 cu. yd., or 735,000 cu. yd. of slide. On the north side of the cut there was a slide for a length of 850 ft. extending back for a distance of 680 ft. from the track. Early in 1914 a smaller slide appeared on the south

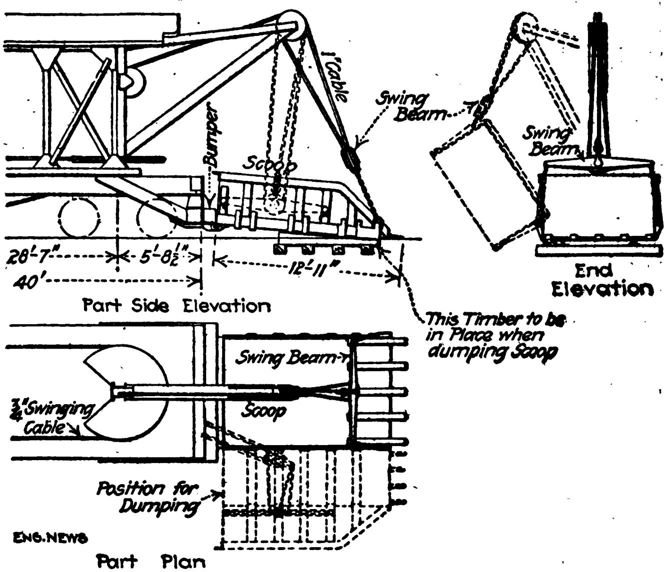


Fig. 9. Front End of Scoop Car Showing Attachments when Excavating and Dumping.

side. This measured 600 ft. along the track and extended back 270 ft. The greatest difficulty was with the first slide in this cut, where the material was a partially formed sandstone. This material broke up as the slide moved toward the track until it had lost all indications that it had ever been rock. This cut carried a very small amount of water. As nearly as could be determined the slide was moving on the harder rock beneath it. A small portion of this rock was encountered at grade.

A Scoop Car for Handling Railway Slides. *Engineering News*, July 16, 1914, gives the following:

The car (Fig. 9) is 40 ft. long over the end sills, or 54 ft. 8 in. over all; it is equipped with a 20-ton crane mounted over the center of the front truck, and having a fixed reach of 12 ft. A double-drum hoisting engine with cylinders 8¼ x 10 in. operates the 1-in. hoisting cable and the ¾-in. swinging cable, the latter passing around a bull-ring at the foot of the mast. There is a vertical boiler 8 x 3½ ft., with the necessary coal space and water tanks. To the hoisting block is attached a swing beam having a chain at each end. The scoop is about 12 ft. long, 7 ft. 8 in. wide and 3 ft. 4 in. deep inside, with a capacity of 10 cu. yd., and it is fitted with heavy teeth on the edge. The car and its machinery weigh about 90,500 lb., which the scoop increases by 16,900 lb.

When excavating, the front of the scoop is attached to the chain hooks and its rear end is held by a pin and backed against a heavy bumper in front of the car, the bumper being supported by inclined braces from the sills. When the scoop is loaded, its front end is raised clear, and the car is run out. At the dumping point, the scoop is lowered upon the rails, with a timber or metal block under one side (as in Fig. 9). The chains are then detached from the end and hitched to lugs on the bottom of one side, so that the scoop can be tilted and emptied.

The car was used in moving a slide on the west bound main track of the Norfolk and Western R. R., which was approximately 110 ft. in length and 5 ft. deep, containing about 800 cu. yd. It required 10 hr. with the scoop car to move this and convey it from 100 to 150 ft. from the point of the slide. The labor cost for handling the above quantity of material, which consisted of dirt and rock, amounted to $182 (including work-train cost, etc.), which is 22.7 ct. per cu. yd. On occasions when it has been necessary to use the scoop car for handling slides it has proved very satisfactory.

Two Methods of Stopping Slides. H. Rohwer, in "Bulletin No. 90" of the American Railway Engineering and Maintenance-of-Way Association, gives the following:

At the west entrance to the Oregon Short Line tunnel in Idaho, where the sides broke off vertically and heaved the track at times to such an extent as seriously to interrupt and delay the handling of material from the tunnel, good results were obtained with ordinary horizontal bracing, in the manner shown in Fig. 10.

A most remarkable slide was encountered on the White River Ry., at the entrance of a tunnel 2,650 ft. long (Tunnel No. 3, at Omaha Drive, Ark.), its magnitude precluding all thought of removing it. The disturbance first manifested itself at a side-

hill cut. In removing the footing, the mass of clay seemed to lose its hold on the rock whereon it rested. It began breaking off, first showing cracks insignificant in size and their location being confined to the right-of-way, but later reaching far out into the adjoining hills, bringing down trees and forming breaks in the surface 15 to 25 ft. in height and perpendicular. The tunnel penetrates a sag in the Ozark mountains, consisting of a boulder formation, lime and rock being found intermixed with clay, a hydrated silica of alumina of brownish color, due to the presence of iron oxide. This clay is very plastic, especially in the ap-

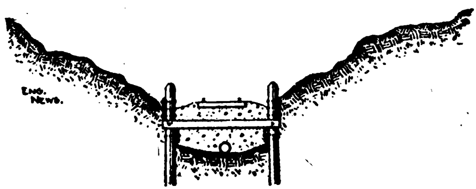


Fig. 10. Method of Bracing a Cut in Sliding Material.

proaches, where action of water is not constant as in a tunnel. Here the layer of clay was from 5 to 100 ft. thick, underlain with strata of solid rock of smooth surface and slanting at an angle of from 5 to 10° toward the creek along which the line had been located, then in course of construction. The grade of the roadbed entered the rock 20 ft. below the surface; in other words, the approach to the tunnel had a 20-ft. rock cut with clay in the slope overlying it.

As soon as cracks appeared on the surface, extra precautions were taken against surface water. The surface ditches were given steeper grades, and, where possible, the bottoms were cemented so that the water could drain off more quickly, thus reducing chances of penetration to a minimum. In spite of this the ground continued to break, and started to move toward the open cut, at first dropping into it little at a time. It gradually increased, until after a rather heavy rain the entire cut was filled with this stuff, involving an expenditure of $1 per cu. yd. for its removal. Though the moving masses had adopted a slope of nearly 1 on 2, the breaks continued, stretching for more than 150 ft. into the hill above the grade of the roadbed, and over 500 ft. distant from it.

To prevent similar occurrences after the road was in operation, the rock cut was arched over for a distance of 600 ft. from the portal of the tunnel (see Fig. 11). An arch, framed of timber,

without protection against "side pressure," cannot be relied upon as a permanent safeguard against slides. To make it serve, however, should the mass continue to move, the clay bank was removed for a distance of 12 ft. from the edge of the rock cut, and holes were drilled into the rock 8 to 10 ft. in depth, and from 10 to 15 ft. apart, in a row along the foot of the clay slope, shots being placed therein and fired simultaneously by means of an electric battery. The rock was broken but not scattered, a trench-like crack appearing at the surface. Logs were cut and placed alongside each other with the butt end in the rock crevices, the other end overhanging the timber arch, and resting upon its top. The material under the logs and between the logs and the arch was

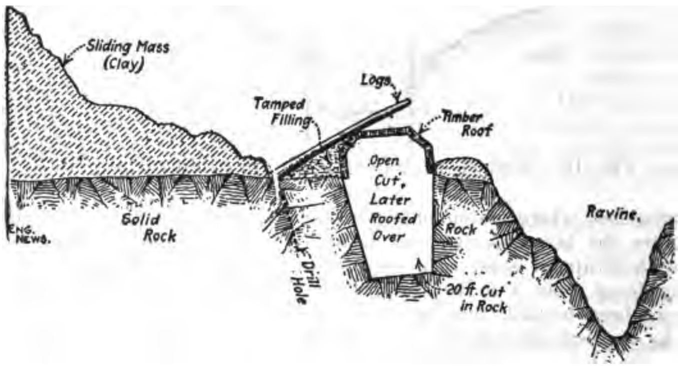


Fig. 11. Cut in Rock Roofed as Protection Against Sliding Clay.

tamped, thus forming a solid flooring over which the material could slide, distributing it over the entire arch and serving as a weight instead of a thrust.

The further object of cracking the rock was to permit the water coming through the clay to escape, thus leaving the footing dry and in better position to act as a support. The plan worked very satisfactorily. The first rain produced another slide, the logs carrying the material over the arch. With the drain in the rock at a distance of 12 ft. from the edge of the cut and over 30 ft. from the foot of the new slope, a good foothold had been created which served the purpose, for no further movement of the overhanging masses (estimated at 130,000 cu. yd.) has taken place since that time (1904). The few sticks of timber in the arch which had moved, were displaced not more than an inch.

Holding Slides by Piles. The following is from a paper by R. P.

Black, *Proc. Am. Soc. C. E.*, Vol. XXXVI, abstracted in *Engineering and Contracting*, June 8, 1910.

The southern portion of the Kanawha and Michigan Railway, for 93 miles (from Point Pleasant to Gauley Bridge, W. Va.), is located on the east side of the Great Kanawha River. For about one-third of this distance the road is close to the banks of the river, on a hillside location, where there is practically no valley, the mountains rising directly from the stream. Owing to the character of the soil, there is considerable trouble, due to landslides and slips, the term slips being used where the fill, or embankment under the tracks, settles or slips toward the river.

At Leon, where considerable expense was incurred in maintaining the track around a slide, the hillside was removed, and the track, for 2,000 ft., was relocated on the rock bottom, obtained by cutting back to a side hill location. By this method the entire landslide was removed and the track put on rock bed, thereby doing away with the trouble, at a cost of $20,000.

At Cannelton, where the largest slow-moving landslide occurred, the ~~main track had~~ been pushed out of line. Reverse curves were made, in order to get back to the alinement, but on account of the continual sliding, the curves became too sharp for operation, and the side track between the hillside and the main track became completely covered. As this slide was of such extent and depth, it was out of the question to remove it in order to get back far enough for a rock sub-grade, as at Leon. The change of line not being feasible, it was proposed to remove part of the landslide, permitting the relocation of the tracks on their original alinement and, after completing this, to protect them from further slides.

A steam shovel was cut in at one end, and removed enough of the landslide to allow the two tracks to be changed to their original location. After the shovel had worked about three days a slide occurred one night, half burying the shovel. Steps were then taken to hold back the hillside before further slides could develop. This was done successfully by driving two parallel rows of piling, 5 ft. apart, about 3 ft. from center to center, as shown in Fig. 12. The upper rows, against the hill, were backed with 3-in. plank, the front rows being driven against this brace in order to aid in supporting the upper row. A 10 x 10-in. stringer was placed against the upper row, and from this 8 x 8-in. braces were carried diagonally, at an angle of 45°, to the lower row of piles, and these were sawed off at the ground level. Steel bands, with 1-in. rods to hold the two sets of piling together, were put on about 8 in. below the top of the brace pile. The depth of penetration of the piling varied from 15 to 30 ft. The piling was

selected large white oak, and oak timber was used for the stringers and braces. Moving the shovel ahead about 30 ft., then cutting it back, and driving the piling as shown, constituted a day's operation. The work was completed successfully without further serious landslides. In four weeks about 12,000 cu. yd. of earth were removed, the track was thrown back to its original alinement, and the landslide was stopped. This work cost $16,000.

The upper limit of the slide is about 135 ft. above the track. The slide consists of about 200,000 cu. yd. of moving earth. This work was done in the spring of 1907, and has been successful. At several places, due to excessive pressure, the braces have been

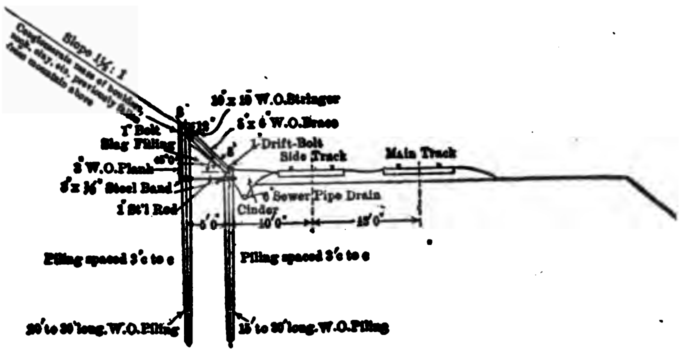


Fig. 12. Pile Brace Against Landslide.

embedded in the stringers. The earth from the top of the piling was given a slope of 1½ to 1. At several other points smaller slides have been stopped with one row of piling. The piles were driven 3 ft. c. to c. and cut off 3 ft. above the top of the rail, the ground above being given a slope of 1½ to 1. At one or two places, where one row was not sufficient, the trouble was stopped with brace piling. At points where the single row of piling showed signs of leaning, due to the pressure against that part of the piling above ground, this overturning, apparently due to too much length above ground, was stopped by cutting off the piling 3 ft. above the ground and giving the earth above it a slope of 1½ to 1.

In contending with landslides of this character in West Virginia, all that seems to be necessary is to obtain a good toe hold, which stops the movement of the earth above. The so-called slow-moving landslides on the Kanawha & Michigan Ry. have been stopped successfully by one of these methods.

The term "slips" is applied to places where the soil slides into the river. These slips occur when the roadbed is constructed on a fill, ranging in depth from 5 to 10 ft., across narrow flats, between the hill and the river. Due to the constant movement of the earth, no trees grow on the land between the river and the railroad. The ground slips gradually into the river where, from time to time, its toe is cut away by the current.

The peculiarity of these slips is the fact that they may continue for one or more seasons without giving any trouble. Slips are due to high water and not to surface water. A quick rise and fall of the river will not cause the soil to move, but continued high water, or several successive floods, will start the slipping action.

In the spring of 1908, the length of track affected by the slips was 7,600 ft., necessitating, at several different points, the maintenance of speeds ranging from 6 to 20 miles per hour for five months, until the dry season, when this slipping action stopped. In Fig. 13 is shown a cross-section of the Brighton slip, which gave the greatest trouble. The section is taken at right angles to the track, the information for which was obtained by levels and test rods driven to rock. A stratum of rock, below the earth, slopes toward the river, ranging from 1:0.2 to 1:1. This rock is covered by successive layers of red clay, varying from 3 to 6 ft. in thickness. Immediately above the rock, and in thin seams, from 4 to 8 in. thick, between the layers of clay, is found a quicksand mixed with fine clay. When the quicksand and fine clay become thoroughly saturated with water, the mixture affords a smooth surface over which the top soil or successive layers of clay slide toward the river. After high water these seams of quicksand can be traced readily by the water seepage. The quicksand is very slimy, and contains no grit. The water must remain over the ground long enough to force its way back into this quicksand and saturate well before the slipping action can take place.

In 1908, in order to keep the track safe, the gangs on four sections were increased from three — the normal force — to ten men each, and these increased forces were maintained for four months. The tracks had to be resurfaced and lined continually. At three different times, it was necessary to put on filling material and ballast in order to keep the track up to grade. This entailed a cost of $4,400 more than the normal expenses for the year. The track over the slips was not only costly to maintain, but dangerous, due to wrecks resulting from derailments on account of rapid settlement of the roadbed.

At Poca, where a trestle was maintained over a slip for about 800 ft., due to the heavy cost of changing the alinement, the

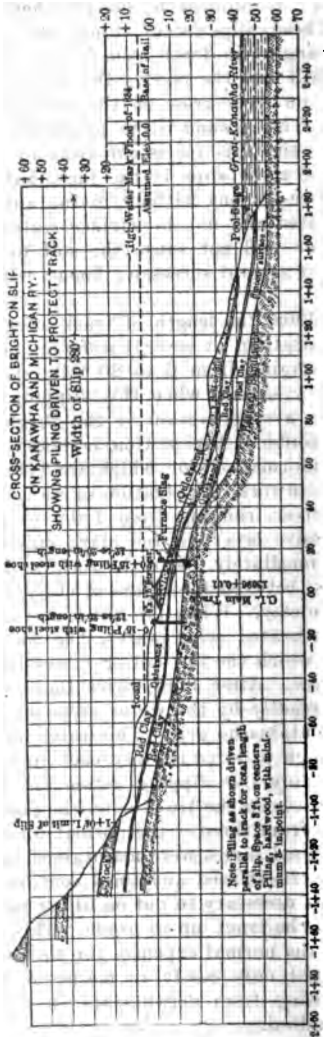


Fig. 13. Cross-Section of Brighton Slip Showing Pile Driven to Protect Track.

trestlework was filled with heavy quarried rip-rap, and the fill was widened so that the stone reached the river's edge. The weight of this stone fill caused settlement, but, after adding stone from time to time for five years, the roadbed became solid. It is thought that the stone fill settled to the rock stratum below the slip, thereby stopping the movement.

In the spring of 1909, test piling was driven for a distance of 50 ft. in the center of the Brighton slip. Transit observations taken from a base line, showed that the piling did not move any appreciable distance. The track held up well within the limits of the piling where, as on either side, it had been necessary to resurface continually.

The test being successful, two rows of piling were driven, one on each side of the track at the Brighton slip, and between its limits, for a distance of 740 ft. The piles were equipped with steel shoes and were driven 3 ft. apart, center to center, on the down-hill side. Continuous 8 x 16-in. timber bracing was bolted to the piling. The work was done with a self-propelling track-driver. A temporary spur track was constructed at one end of the slip, thus dispensing with the services of a work train. The cost of this work was as follows:

Hardwood piling, 8,075 ft. at 13 ct.	$1,049.75
Steel shoes, 12,690 lb. at 3 ct.	380.70
Labor	856.35
Fuel, etc.	120.00
Total	$2,406.80

Up to the present time (Sept., 1910) this remedy has been successful.

At another point, where the rock strata are not at great depth it is proposed to go down the hillside about 20 ft. from the track, put down holes about every 20 ft., and blast the smooth surface of the rock. Thus, by roughening the surface and destroying the stratification, the sliding of the clay may be stopped.

Stopping a Slide by the Use of Explosives. *Engineering News*, July 1, 1915, gives the following:

The Pennsylvania Co. on its C. & P. division recently built a spur track about a mile long from its main track to the plant of the Pittsburgh Crucible Steel Co. at Midland, Penn. In excavating for the new roadbed, which for a portion of the way lies along and below the Ohio River Passenger Ry., a bad slide developed about 1,700 ft. long, extending back from the cut a maximum width of about 350 ft. to the face of a rock cliff. About 40,000 cu. yd. of material in excess of the preliminary estimate slid into the roadbed prism and was removed by a steam shovel.

Fig. 14 shows an approximate typical section through the slide. For a time it was necessary to abandon the track on the side toward the new cut, using the other track past the slide. The track being used was lined back up the hill from time to time and brought to surface with blast-furnace slag.

In a thorough study of soil conditions it was found that a sliding plane existed at the top of a bed of fire clay about 10 ft. below the surface of the sliding mass.

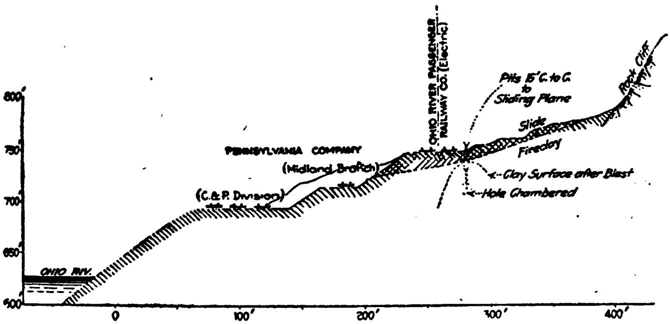


Fig. 14. Cross-Section Through Slide.

Holes large enough for a man to work in were dug on 15-ft. centers to the surface of the fireclay. Then a 2-in. hole was drilled 10 ft. into the clay and the lower end chambered with two sticks of 40% dynamite. Three kegs of black powder were then placed in the enlarged hole and the charge fired. The clay was lifted into mounds which connected into each other at about the surface of the clay. This method of stopping the slide proved a complete success.

European Railway Practice for the Prevention of Slides. There is much in print on this subject by both French and English engineers. Many of their methods can have but little application in the United States. However, it is desirable to know a great variety of methods of overcoming slides. Even the most laborious of European remedies may find occasional application in America. The following is from "Notes on the Consolidation of Earthworks," by Jules Gaudard (translated from the French by James Dredge, C. E.) and published as paper No. 1274 in the *Proceedings of the Institute of Civil Engineers*, Vol. 39 (1874–5):

The theory of the thrust of earth against retaining walls is well known. In Fig. 15, the retaining wall is designed to hold against the thrust of the prism ACX sliding along the line CX.

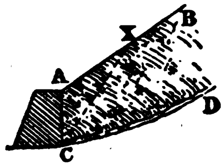


Fig. 15.

Fig. 16.

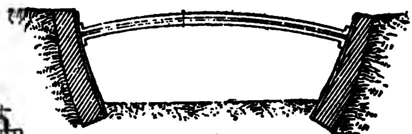


Fig. 17.

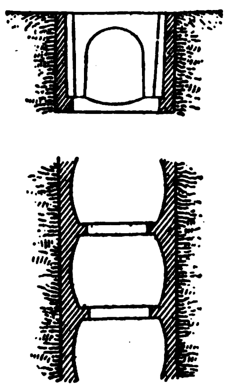


Fig. 18.

If however there is a water bearing seam at CD the hypothesis of the theory of earth thrust is not tenable, and it may be impossible to construct a stable retaining wall.

Earth laid in layers behind a retaining wall possesses a sliding tendency which destroys the hypothesis of the homogeneous theory. It is preferable to place the earth in well rammed layers in such a manner as to form stratifications the sliding angle of which is in the opposite direction to the thrust against the wall.

Where sliding ground makes retaining walls unfeasible the earth must be retained by strutted walls provided with sufficient outlets for drainage.

The walls of the Billsworth cutting (London and Birmingham Ry.) are strengthened by counterforts strutted underneath the road bed (Fig. 16). Over head strutting is applied in the case of high walls which threaten to turn over rather than slide out at the base, as for example on the inclined plane at Euston, Fig. 17.

Fig. 18 shows an arrangement of masonry struts, with counterforts spaced 21 ft. apart; the wall itself being counter arched between counterforts, to check it from yielding under pressure from the back. Masonry struts, placed 15 ft. apart, and of the form shown in Fig. 19, serve to strengthen the retaining walls of the Chorley cutting (Bolton and Preston Ry.). These are formed with upper inverted arches to give them additional stiffness. When the cuttings are in side-lying ground the struts should be inclined, as in Fig. 20.

Where there is only one side of a cut to be retained or where the two sides are very unequal thick dry stone walls may be employed, strengthened by long internal counterforts, as in Fig. 21. This class of masonry acts as an efficient means of draining the slope behind and it gradually becomes hardened into a compact mass, forming, together with the counterforts that strengthen it, a body of firm earth and stone able to retain the mobile material above.

Fig. 22 shows an inclined wall with counterforts used on the Versailles railway. The slope of the cutting of Brigant (Blesmes-Gray) is supported by inclined arches laid on the slope, the space between being filled with dry stone. The bases of the piers rest upon a continuous footing along the side of the roadway, connected with a similar one on the other side by means of inverts. The slope is drained by pipes leading to a central culvert at C below the invert, Fig. 23.

Causes of Landslides. In considering the physical properties of earth and their relation to slides attention is called to the marked tendency of clays to shrink and crack as they dry out.

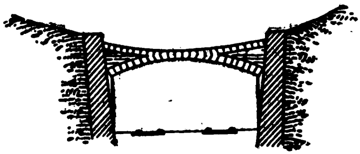


Fig. 19.

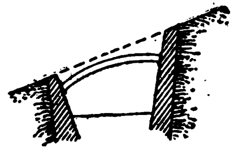


Fig. 20.

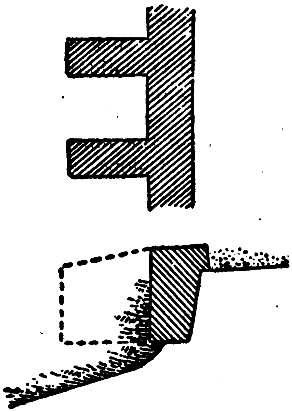


Fig. 21.

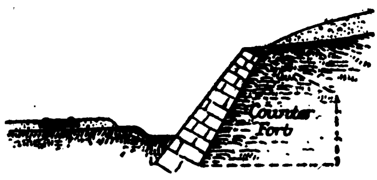


Fig. 22.

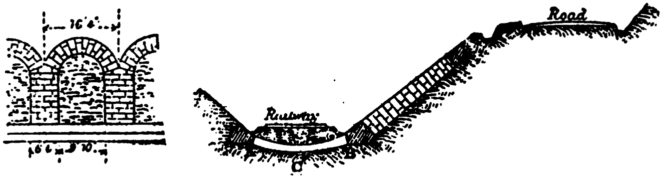


Fig. 23.

Rain penetrates these cracks or fissures and soaks into the clay which expands. Renewed dryness opens the cracks wider than before. If, in connection with these fissures on the surface, underlying water-bearing seams exist in the clay, slides are very likely to occur. In Fig. 24, when the fissure A B descends near enough to the water-bearing seam C E the fall of the mass ABCE is imminent although no disorganization other than the fissure A B has occurred.

The chief means of dealing with these slippery formations consist: (1) in insuring the free discharge of the water by means of channels, drains or filters in such a manner that the ground shall be gradually dried and consolidated; (2) in taking off the rain or surface water as rapidly as possible, by means of impermeable coverings, benches, or ditches; (3) in preserving the loamy soils from the action of the sun, rain, and frost, and sometimes in protecting the foot of slopes with walls or simple counterforts of well-rammed earth.

Concerning the proper slopes to be employed in cuttings in bad ground it is well to increase them to 2 or 3 of base to 1 of height instead of employing 1½ to 1 or 1 to 1 which are applicable in good material.

Cuttings. The side slopes of a cutting may be drained by the construction of channels (Sazilly system) if the water-bearing seams are clearly defined; by pipe drainage if the distribution of water is more vague and general; and lastly, by filtration in the case of water bearing sand.

Water Bearing Strata. In water bearing strata, in some instances, a deep narrow trench has been excavated in the bank at a sufficient distance from the face of the slope. The trench is timbered and filled with dry stone, as in Fig. 25. The planes of moisture in the prism A B C dry up, and the earth gradually and surely becomes consolidated. This method is good but costly; it may be employed to arrest movement already commenced.

Sazilly devised a more economical system of small longitudinal drains established near the face of the slope, and formed in the vicinity of the seam. At the bottom of a cutting in the face of the slope, is placed a channel formed transversely of three flat tiles set in hydraulic mortar. Or the channel can be formed with a single row of half round tiles. Round or broken flints 2 in. in diameter, or sometimes furnace slag, are thrown over the channel. The largest pieces are placed below and the smallest nearer the water bearing seam. This stone filling, heaped against the vertical side of the cutting in the face of the slope, is always high enough to cover any irregularity in the line of the water discharged. The surface may be covered with turf or with a layer

of clay or matting, with tiles or with flat stones to keep out the mud which would gradually choke the drain. Two lines of water discharge at least 18 in. apart can be served by the same channel. This system of drainage is laid in the face of the slope with gradients of at least 1 in 100. See Fig. 26.

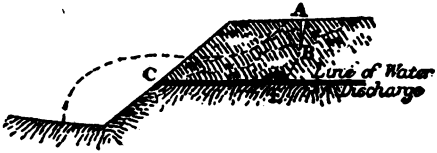


Fig. 24.

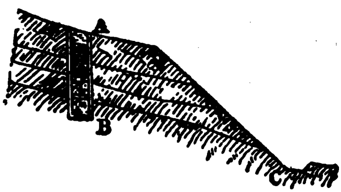


Fig. 25.

Fig. 26.

A slope of loamy soil should be completely covered against the action of weathering. The revetment may be executed of rammed earth in successive layers from 6 to 8 in. thick, laid with a slope opposed to the face of the bank. The face of the bank should be furrowed as in Fig. 27 if the slope is steep. Ordinary turfing would be insufficient, whereas sods laid as in Fig. 28 would be costly, and still permit water to enter between the interstices.

In deep cuttings commanded by higher natural slope it is of great importance to check the action of the surface water. With this object a ditch is formed at the foot of the natural slope,

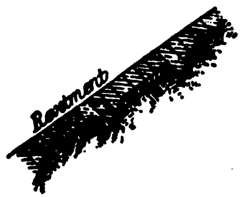


Fig. 27.

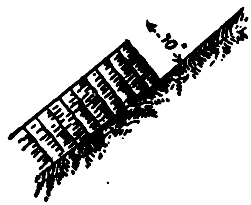


Fig. 28.

as in Fig. 29. This ditch must be of clay, puddled to make it impermeable. An open channel in stone or brick, as in Fig. 30, is better as it is less likely to let water percolate. A still better

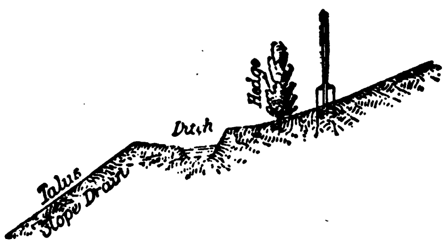


Fig. 29.

method consists in dividing the face of the slope into a number of stages in such a manner that the action of the surface water is greatly reduced. The top of each stage or bench is given a

Fig. 30.

reverse slope of 15%, forming a channel which conducts water to drains laid at intervals on the surface of the slope, as in Fig. 31. The channels up the side of the cutting, which take off the water

from the trench drains can be formed of small stones covered by the revetment, and resting on the natural ground, as in Fig. 32.

Pipe Drains. When water-bearing seams are numerous, irregular, or indistinct, pipe drains may be employed wherever any

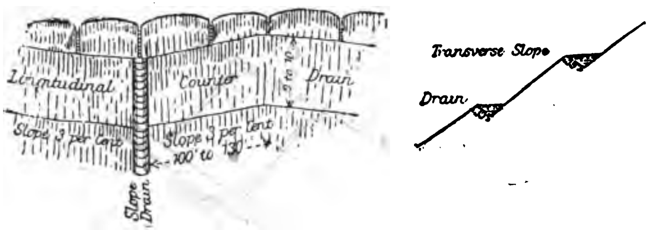


Fig. 31.

discharge of water shows itself. On the Croydon and Birmingham railways in England the efficiency of pipe drains has been increased by making numerous small openings in them, enlarged toward the inside, as in Fig. 33. Owing to the form of the holes any mud which may enter from the outside of the drain frees itself immediately and passes off with the water.

A line of drain pipes is placed along the crest of the slope, and

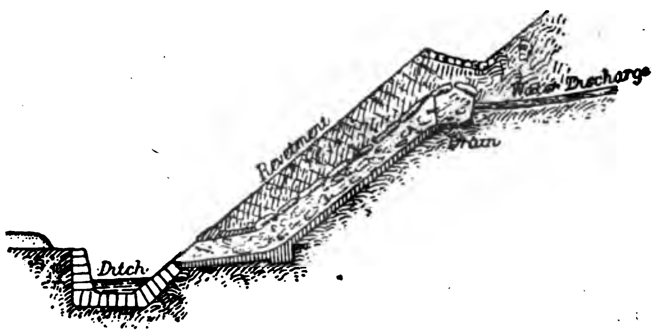


Fig. 32.

from this line others decend transversely into the side ditch. At regular intervals a vertical pipe, C in Fig. 34, rises from the main line for the purpose of ventilation. The circulation of air thus obtained causes the deposit left in the pipe in dry weather to crack, and thus it is easily removed the first time water passes

through the pipe; on the other hand this arrangement causes a choking vegetable growth within the drain. The pipes are laid 5 or 6 ft. below the surface, toward the foot of the slope and 3 ft. beneath at the top. They are spaced about 15 ft. apart.

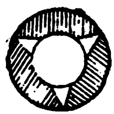


Fig. 33.

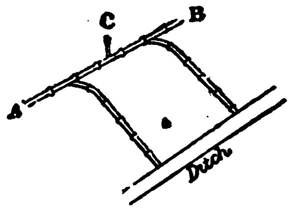


Fig. 34.

Fig. 35 shows an arrangement used on the railroad from Blesmes to Gray, France; drain pipes 1.8 in. in diam. are laid 39 in. below the slope and from 10 to 20 ft. apart. These discharge into longitudinal collectors placed near the side ditches. A third central collector drains the roadway and is placed in connection with the two lateral drains by pipes laid from 32 to

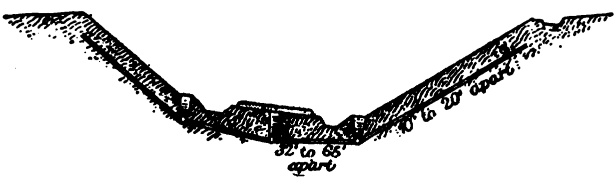


Fig. 35.

65 ft. apart. They are formed by pipes 3.34 in. in diam. and are covered with broken stones.

Fig. 36 shows a drainage system used on the Eastern railway of France. Drains at least 2.36 in. in diameter, surrounded by a filtering material, and with a minimum inclination of 1 in 200, are laid in a deep narrow trench M N to the rear of the top of the slope. On that side of the trench farthest from the face of the slope are placed small vertical pipes about 6½ ft. apart. These pipes are stopped short of the surface of the ground and communicate below with the longitudinal drain. The trench is then filled with earth and well rammed. Other collectors beneath

the side ditches drain the formation to a depth of 4 ft. The mass M N E C D being thoroughly drained by this means, acts as a counterfort to resist the thrust of the moist ground behind M N.

The Ashley cutting on the Great Western railway, England, was drained by a system of inclined transverse galleries and sumps, connected by a longitudinal gallery in such a manner as to tap all the water-bearing seams. On the Great Eastern railway the slopes were drained by sumps filled with broken stones, and by discharge pipes.

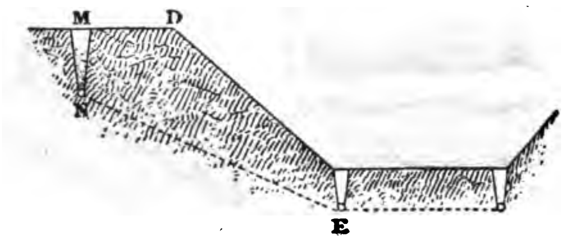


Fig. 36.

A cutting in the North of Spain was attended by land slips, although the stratifications were normal to the face of the upper slope. In such a case water is retained in pockets and can be removed only by a syphon. Collecting wells were sunk and surrounding trenches were made as well as a system of galleries.

On the Western railway of Switzerland drain pipes were laid in the slope, as shown in Fig. 37, in such a way as to drain a considerable thickness of earth. A number of pipes are joined to-

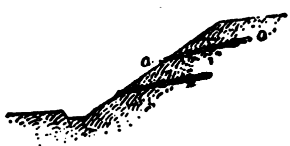


Fig. 37.

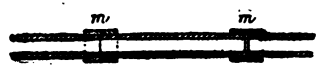


Fig. 38.

gether with sleeves, as shown in Fig. 38. These sleeve joints are kept in place by means of an iron wire from one to another. The built up length of pipes is shoved into a hole in the face of the slope formed by a boring tool.

Filter Drains. In water-bearing sands which discharge from their whole mass, drainage can be only partially successful, and it is necessary to have recourse to filtering appliances, covering

the whole of the slope which is to be consolidated. On the Northern railway of France there is reset a stone facing from 5 to 6 in. thick, covered with stone packing or turf 12 in. thick. A 9 or 10-in. revetment is sufficient to keep out the frost which would stop the water discharge.

Gravel fascines, shown in Fig. 39 and 40, should be used where there is an abundant flow of water. They are formed of envelopes of brushwood fastened with iron wire and filled with gravel

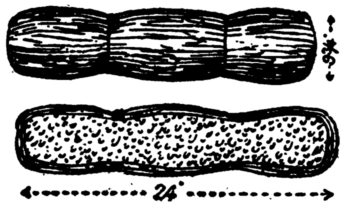


Fig. 39.

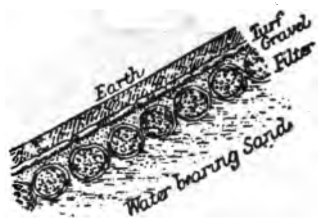


Fig. 40.

or broken stone. These fascines are laid in horizontal furrows formed in the face of the slope. A layer of gravel 4 in. thick is put on to equalize the surface, and the whole covered with turf or dirt.

Sometimes in very fluent sands the side ditches of the road bed fill as fast as they are made. The most efficient remedy against this is to place, first, two fascines as shown in Fig. 41, and to excavate the intermediate material. At the end of a few

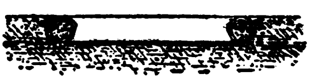


Fig. 41.

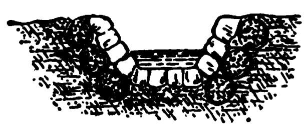


Fig. 42.

days the upper bed will be drained and two other fascines may be laid at a lower level and so on, finally the ditch is lined with stone, as in Fig. 42.

Restoring Cuttings After Landslips. When a landslip is not very considerable it is sufficient to raise it completely and promptly, so as not to allow time for fresh slips. The new ground is then drained and strengthened with a counterfort. On the line from London to Birmingham and on the Croydon rail-

way some local slips were restored with counterforts of dry stone and gravel.

In some cases it may happen that the glacis of a slip, MN Fig. 43, may be below the level of the side ditch. It is then advisable to build it up again with carefully rammed earth.

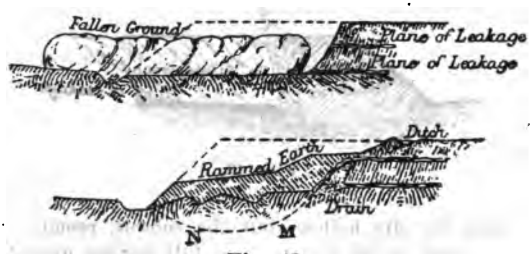


Fig. 43.

With land slips of a larger scale, in many cases the principal part of the fallen earth may be left in place. Fig. 44 shows the treatment of a land slip in the Hundsoff Cutting of the Wissembourg railway. An excavation A B C D was made of sufficient extent to lay bare the undisturbed ground, and at the foot an open drain, C, was formed. If the material is very soft this excavation must be timbered, but it is sometimes firm enough to

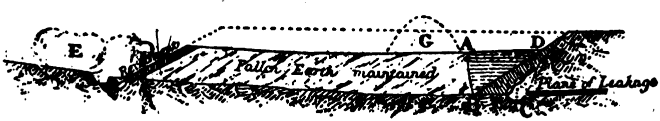


Fig. 44.

allow the earth excavated to be thrown temporarily on top of the slip, as at G. The drain is covered with turf, then a rammed earth counterfort, B D, is formed and finally the excavation is refilled with earth from G. If the fall of the water-bearing seam is insignificant it is necessary only to clear away the portions E that have fallen on the way. A new face slope is formed, which is covered with 12 in. of rammed earth. The top surface of the slip ought to be evenly dressed and all cracks stopped up to prevent entrance of rain water. In land slips of considerable length parallel to the way, it is advisable to form transverse cuttings at intervals, connecting the low points of the drain with the side ditch.

It is especially advisable in cases where the angle of slip is considerable, to prevent the recurrence of such an accident by retaining the ground with a rammed earth bank, separated from the slip by a filtering wall of broken stones, as in Fig. 45.

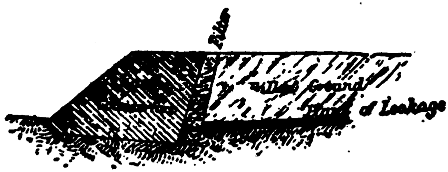


Fig. 45.

Sometimes the slip hollows out the subsoil, remains more or less charged with water and tends to fall further upon the road-bed. It is then preferable to excavate the upper portion, M N P in Fig. 46, and at the same time the face, N P, is exposed for drainage.

Fig. 46.

The Consolidation of Embankments. The simplest treatment for yielding foundations is to add material to the embankment until subsidence has ceased. This is often too costly and other means of consolidation are required. The condition of the subsoil can sometimes be improved by driving a large number of short piles or by excavations in the form of truncated pyramids, filled afterwards with compact clay. Generally the true solution consists in draining the subsoil.

Fig. 47 shows the method of draining the foundations of an embankment at Val Fleury on the Versailles railway. Two large parallel drains were formed on the lower side. These drains, from 39 to 50 ft. deep, were connected together and led all the water away in such a manner that the foundation was dried, and was surrounded and maintained as by a protecting belt.

Between Otzaurte and Oazurza in the North of Spain, moist valleys are met with, where the soil of clay and marl slips on schistose strata. Several embankments on the northern line yielded at the base, and it became necessary to surround the area

on which they stood by a double network of drains; encircling ditches with discharge culverts for the surface water; then for the internal drainage, galleries 5 ft. high and 39 in. wide were driven along the schist, and cutting into it from 15 to 20 in., in order to stop subsequent movement and to drain the sliding surface. These galleries followed the irregularities of the rock in such a manner as to involve slopes of from 1 in 33 to 1 in 17. They were then filled with a mass of broken stone leaving a space at the top clear of the fissures which admit the water.

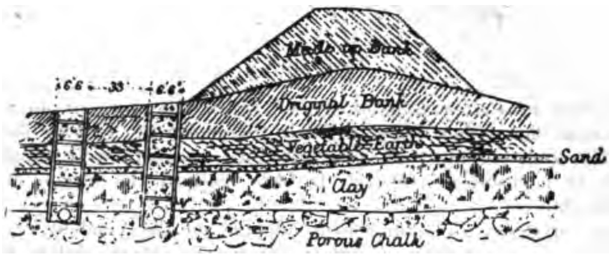


Fig. 47.

Sliding Embankments. Embankments are often built without consolidation for the sake of economy. If they are of poor materials and become saturated they are apt to slip. Where a central core is made by end dump and the embankment widened by side dump, slipping is very likely to occur. Such an embankment may be thoroughly consolidated by the addition of counterforts of carefully rammed earth, separated from the earthwork by a filter of broken stone, about 1 ft. thick, or by a wall of gravel fascines. See Fig. 48. It is preferable to execute these counterforts in advance with earth taken from the site as at a b c d e a. By doing this they can have time to consolidate. They should be

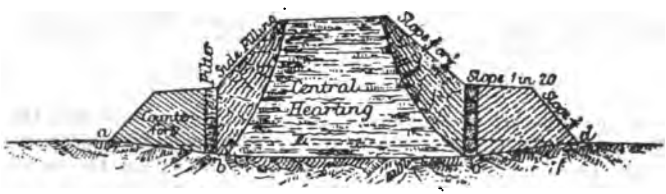


Fig. 48.

rammed in inclined layers in a direction the reverse of the slope of the embankment.

On side lying ground an embankment may slip even if formed of good material. It is necessary in such cases to trench out the natural surface, as in Fig. 49 in order to give sufficient hold.

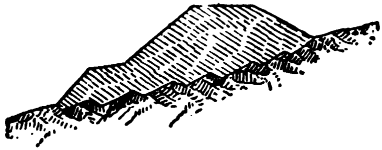


Fig. 49.

Repairs of Fallen Embankments. When the slope of an embankment has fallen, it is advisable to remove the foot by short lengths, and to replace the excavation at once with well rammed earth in horizontal layers, or in beds inclined the reverse way of the slope.

Fig. 50 shows an arrangement adopted on the Vendeuvre embankment for a length of 230 ft. A portion of the fallen material was left, being covered with a counterfort of rammed earth and new ground above, while the drainage was effected by means of a gravel filter standing in a brick channel.

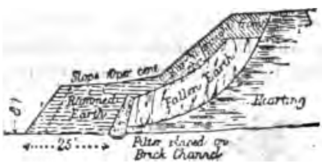


Fig. 50.

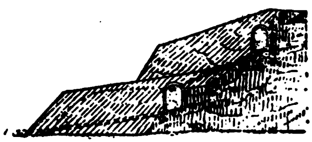


Fig. 51.

On the Moncerf embankment (Paris-Coulonmers railway) the filter is of broken stone surrounded by matting. At some parts it was necessary to form two of these filters within the fallen portion of the work, Fig. 51. They are connected together and to the outside slope by transverse drains. Two superimposed counterforts retain the filters.

On the Main-Weser railway some clay embankments slipped and were restored with sand. Pockets filled by sand became saturated with water and were drained by pipes covered with 5 ft. of broken stone, A B in Fig. 52.

On the Wissembourg railway the sides of the fallen embankments were drained by means of transverse trenches in which

were placed gravel fascines, as in Fig. 53. These were afterward covered with a facing of good earth combined with the fallen material, and well rammed.

Fig. 52.

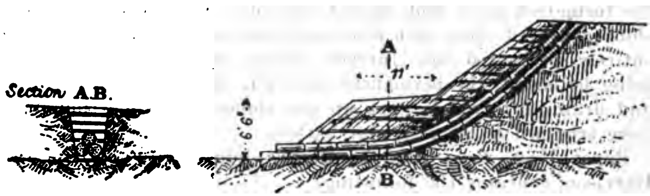


Fig. 53.

Stopping Slips on the Nottingham and Melton Ry. This work is described by Edward Parry, in paper 1756, *Proc. Inst. C. E.*

In the cuttings through the boulder clay where the material was homogeneous no slipping to any appreciable extent took place, but where pockets of sand occurred in the shale and clay, the slopes gave considerable trouble, continually breaking off vertically at the back from the top, after being trimmed to a slope of 1¾ or 2 to 1. Water was generally found in the sand, at the base of the slips, and was apparently the cause of them. These when small were frequently cleared away entirely down to the solid, and the line of slope restored by filling in with burnt ballast, broken boulders, or other convenient hard dry material, which allowed the water at the back to drain off without doing further injury. Where, however, the slip was very large, extending, as in one case at the north end of Stanton tunnel, 6 or 7 chains along the slope, and from 20 to 40 ft. in depth, another method was pursued: a deep drain parallel to the line of railway and 4 or 5 ft. wide was taken down at the back of the slip to the solid ground, and filled with burnt ballast; cross drains were cut from it to the face of the slope to bring out the water, and the toe of the slip was secured by being burnt for a width of about 20 ft., the whole being finally trimmed off to a flatter slope.

Two large slips occurred in cutting No. 9 in the lias shales, on opposite sides of the line, somewhat similar in character to

those before described, breaking off vertically at the back from near the top of the slope. In this case the bottom of the slips extended underneath the formation of the railway, and the toe of the one being pressed on to the toe of the other, by the weight at the back, caused both slips to turn and rise upwards, lifting the ground several feet. In fact, a gang of men had to be continuously employed lowering the temporary roads in order to keep the work going. These were dealt with in the following manner: — In addition to drains at the back and a toe of burnt ballast on each side, the slips were cut down to the solid ground in the center line of the railway, varying from 3 to 9 ft. under the formation level, and cleared out for the full width, the space thus excavated being then filled in with rough furnace slag, which entirely prevented any further lifting, and upon which, after being ballasted, the permanent way was laid. The burnt ballast and drains afterwards kept up the slopes of the cutting, which were trimmed to an irregular batter.

Paper 1760, *Proc. Inst. C. E.*, by John William Drinkwater Harrison, contains the following:

In treating slips on the Nottingham and Melton railway two methods were mainly adopted.

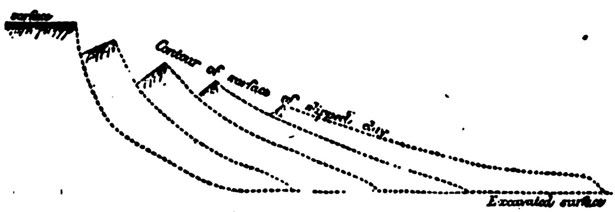
1st. The toe of the slip was burnt into a compact mass of ballast, the width at the base varying from 8 ft. to 20 ft. or more. This retaining wall, for such it virtually was, having been formed, the foot of the slip was weighted as far as possible, and the slope was left concave where practicable, having a versed sine one-thirtieth of its length. The foundation of the ballast heap was 2 ft. below the original surface. In no case did this wall of ballast give way, though in several instances the slip rolled completely over it, and a fresh heap had to be formed at a greater distance from the line. As the circumstances were exceptional, any details as to cost would be misleading; but it may be stated that 1 ton of coal was sufficient to burn about 10 cu. yd. of ballast.

2nd. Trenches were cut through the slips at right angles to the direction in which the ground was moving; the width of these trenches varied from 2 to 9 ft., and having been carried 18 in. or 2 ft. into the solid ground below the line of the slip, they were filled with stones, the whole of the timbering necessary for their excavation being, generally speaking, left in. This is obviously a costly process, and was only adopted in extreme cases, where the slips were delaying the opening of the line. In excavating the trenches it was noticed that but little water was tapped at a lower level than 3 or 4 ft. below the surface. That they must be regarded as counterforts to strengthen the slips

more than as means of drainage was shown by the fact that several weeks after their construction the surface of the bank 3 ft. away from the trench was in a soft, boggy condition. Regarding them, then, simply as counterforts intended to strengthen a moving mass of weak material, it was thought that to carry them completely through that mass would defeat the purpose for which they were formed, and allow the slip, or succession of slips, to continue their course between the walls. It was found that carrying them about two-thirds of the way through the slip effectually checked its progress, and it seems probable that a less distance than this would have sufficed.

In all cases, where the trenches extended to the back of the slip, there was no great quantity of water. The cause of the majority of the failures appeared to be the inability of the material to support its own weight, consequent on the quantity of water with which it was charged; that this water is held in suspension for a great length of time appears probable, and the fact that the heaps of ballast over which the slip had rolled were found, when opened out, to be in a dry and dusty state, shows that the plastic nature of the clay prevents gravitation, and the process of evaporation in a deep bank must be slow. More than once where the base of the slip was on the same level as, and extended to the bottom of, the ordinary open side ditch, a pipe-drain filled with rubble was substituted with advantage.

Improving Sliding Material by Burning. William George Laws describes, in paper 1810 in the *Proc. Inst. C. E.*, a method of combatting slides on the North Eastern Ry., England. The line runs through the alluvial clay on the north bank of the river



Section of Brick-fields.

Fig. 54. Section of Bank in Brick Fields.

Tyne. This is a tenacious flaky brown clay; the flakes, which vary from 1/8 in. to 1 in. in thickness, being separated by films of fine sand, and holding water obstinately. The upper and lighter-colored bed varies from 6 to 12 ft. in thickness, and be-

low this lies a bluer-colored, more unctuous clay, similar in its flakes and partings to the browner clay above.

The lower bed is extensively worked for brick making. In the brick fields, where no attempts to hold up the banks is made, the nature of the slipping is clearly shown. The banks break as in Fig. 54, slopes of 10 or 12 to 1 being reached without the material coming to rest.

Fig. 55 shows how the clay slid into the railway cuts, and the method adopted for burning it.

On a decided slip occurring the first thing done was to clear away a space of 15 to 20 ft. in the line of the cutting, until the solid clay was reached both downwards and sideways. A good

Fig. 55. Line of Slip in Cut and Method of Burning Clay.

fire was then lighted on the solid ground, using plenty of broken wood and coal, and allowed to burn up well; on to this the clay was cast from both sides, in layers varying from 12 to 30 in., small coal being spread between, until the heap was from 8 to 12 ft. high. This was allowed to burn out on the one side and continually extended on the other, as in firing a clamp of bricks. The burnt material from the cool side was then cast back as soon as possible into the void in the slope, and trimmed to shape.

The plan adopted was generally successful, though in some of the earlier cases, from sufficient care not having been taken to get well down to the solid clay, slips occurred for a second time, when the process had to be repeated to a greater depth. It was found that a bed of heavy slag and hard stones, roughly laid on the solid ground as a bed for the fire, very much helped the process by giving a free draught. The general form and position of the heaps is shown in Fig. 55. The material when burnt occupied by estimation from 20 to 25% more room than before, leaving a considerable surplus of burnt stuff to go to bank.

The Drainage of a German Railway Embankment. *Engineering News*, May 10, 1890, gives the following: The Westerwald railway has to pass over several large clay beds. At one point a large embankment started to settle unevenly, sinking in one place and rising in another. Attempts were made to widen the embankment and counter weight the section that had a tendency to rise. These operations being unsuccessful an elaborate scheme of drainage was resorted to.

A large culvert was put under the embankment in a tunnel, and was located very low (see e f in Figs. 56 and 57). The width within at the bottom was 4.1 ft., at the top 2.3 ft., the height was 5.58 ft. It was planned so as to tap the greatest possible number of subterranean streams and also to carry off the water in the neighborhood of the broken drain. The culverts, which were filled with broken stone, served also to drain the subsoil

Fig. 56. Section of Sliding Embankment.

on which the structure rested. In this, they are aided by a ditch *g h*, with a broad and deep section, the bottom being below the upper surface of the clay bed. All water falling above the embankments will be collected in the ditch and lead to the mouth *f* of the main drain. From there it passes through a 1.5 ft. iron pipe laid in the culvert.

The nature of the case made it necessary that the side drains should penetrate the mass of the embankment as well as the surfaces of motion. The main conduit, however, it was necessary to protect from all chances of failure; hence its deep position. The side-channels were inclined as shown in Fig. 57.

The drains could have been dug without wooden linings, but the clay of the bed in which the side drains terminated became so soft on exposure to the air that it was necessary to put in a heavy wooden casing throughout the entire system. After the main conduit was built and the side culverts were being dug, the pressure of the moist clay was great enough to several times break the woodwork. It sometimes became necessary to widen the drains also on account of the diminution of the section due to the same cause, even if the lining was still intact, though bent.

The side drains were driven as far as the ground remained damp. Then they were filled with broken stone. The final step was to lay the iron pipe before mentioned in the principal culvert, and to complete the filling of the entire culvert with stones. The method of joining the pipes is of interest. Each section

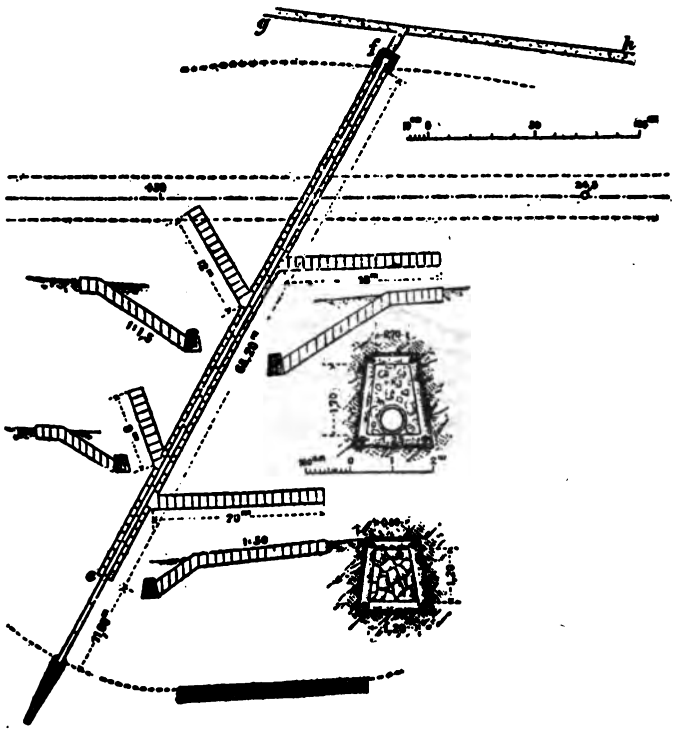


Fig. 57. Plan and Sections of Culvert Used on Westerwald Ry.

was about 13.5 ft. long. These had to be connected in such a manner that any motion of the drain would not destroy the conductivity of the line. This was accomplished as shown in Fig. 58. Two pipes are connected to each other by ties running their entire length; then these pairs are joined in the same way. The way in which the ties and the pipes are connected is shown in Fig. 58. The rods are bent at one end, laid

against the pipe, and a ring slipped over the ends. The other extremities pass through a flange of angle iron fixed on the second pipe, where they are held in position by nuts. Two ties are used for each pair of pipes and they are placed at right angles on the successive pairs.

Since the completion of the work, all motion of the embankment has stopped.

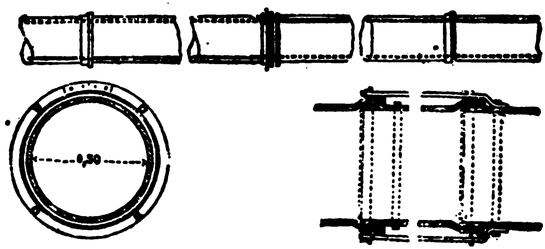


Fig. 58. Method of Connecting Culvert Pipes.

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INDEX

D

F

G

H

I

J

K

L

U

V

W

Y.